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ASTRONOMY and ASTRO-PHYSICS.

JUNE, 1892.

CONTENTS.

GENERAL ASTRONOMY:

Colors Exhibited by the Planet Mars. *William H. Pickering* 449
The Total Solar Eclipse, April 15-16, 1893. *H. S. Pritchett* 454
Explanation of the Mystery of the Egyptian Phœnix. *T. J. J. See, Berlin* 457
Observations of Nova Aurigæ at Vassar College Observatory. *M. W. Whitney* 461
Preliminary Address of the General Committee of the World's Congress Auxiliary on Mathematics and Astronomy. *George W. Hough, Chairman* 462
New Binary Star β 208. *S. W. Burnham* 464
52 Herculis (β 627). *S. W. Burnham* 465
Orbit of β 612. *Professor S. Glasenapp* 466
Notes from the Time Service of Washburn Observatory. *S. D. Townley* 467
The Earthquake for Februrary 23, 1892. *William H. Pickering* 470
The German Variation of Latitude Work. *Harold Jacoby* 471
Physical Observations of Mars by Dr. Terby. *Translated from the French by Roger Sprague* 478
The Physical Nature of Shooting Stars and Aerolites. *W. F. Denning, England* 481

ASTRO-PHYSICS:

On Electrical Discharges through Poor Vacua and on Coronoidal Discharges. (Plate XIX and other illustrations.) *M. J. Pupin* 483
On the Line Spectra of the Elements. *C. Runge* 496
On the Large Sun-spot of 1892, February 5-18, and the Associated Magnetic Disturbance.. 499
On a Remarkable Prominence. *H. Deslandres* 502
The New Star in Auriga. *Agnes M. Clerke* 504
A Study in the Variation of the Solar Diameter. *Orray Taft Sherman* 513
The Temperature of the Sun *H. LeChatelier* 517
Solar Observations During the First Quarter of 1892. *P. Tacchini* 520
Astro-Physical Notes 520–529
M. Lecoq de Boisbaudran's Observations on the Electric Spectra of Gallium.—The Aurora of April 25.—Solar Halo and Mock Suns.—Wolsingham Observatory Circular No. 32.—Kayser and Runge on the Spectra of the Elements.—Spectrum of Comet *a* 1892.—Photography of the Ring Nebula.—A Large New Nebula in Auriga.—The Portrait Lens in Stellar Photography.—Photography of Colors.—Magnesium as a Source of Light.—Magnetic Storm of February in Mauritius.—Periodicity Common to Sun-Spots and the Aurora Borealis.—Connection Between Sun-Spots and Magnetic Storms.—The Great Sun-Spot and its Influence.—Absorption Spectra of Metallic Films.—The Visible Spectrum of Nova Aurigæ.

CURRENT CELESTIAL PHENOMENA 529–537
Planet Notes and Tables for July and August.—Occultations Visible at Washington.—Mr. Marth's Ephemeris of the Satellites of Saturn.—Configuration and Phenomena of Jupiter's Satellites.—Minima of Variable Stars of the Algol Type.—Occultations of Stars by Planets.—Brightness of Asteroid No. 324.—Phases and Aspects of the Moon.—Twenty-two Asteroids Discovered in 1891.—*Comet Notes*:—Orbit of Comet *a* 1892 (Swift).—Ephemeris of the Same.—Ephemeris of Winnecke's Comet.—Search Ephemeris for Comet Brooks, 1886 IV.—Observation of Saturn.

NEWS AND NOTES 538–544
Total Solar Eclipse, April 15-16, 1893.—The Milky Way by Otto Bæddicker.—Aurora at Mt. Hamilton.—Aurora at Providence, R. I.—Occultation of Uranus, April 12.—Proceedings of Haverford College Observatory, 1891.—Annual Report of the Observatory of Paris.—The Opposition of Mars in 1892.—Book Notices.—Publishers Notices.

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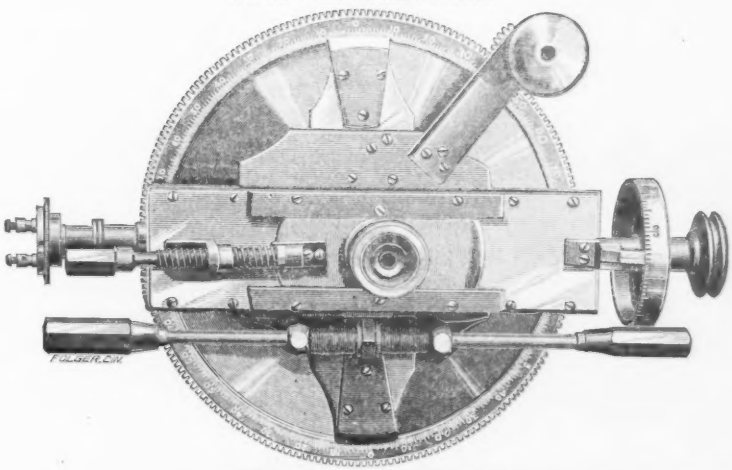

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General Astronomy.

COLORS EXHIBITED BY THE PLANET MARS.*

WILLIAM H. PICKERING.

The following preliminary account of an investigation made in Cambridge at the last opposition of Mars, is published at this time, in the hope that others may take advantage of the present favorable circumstances, to verify the results here described. One of the most difficult branches in practical astronomy is that pertaining to the colors of the heavenly bodies, for no other optical illusions can be found to be so complete as those pertaining to color. The planet Mars is frequently spoken of as the red planet, yet its color is by no means as red as that of an ordinary candle flame. To illustrate this fact, let the observer so place himself that the planet Mars, an electric light, and a candle or gas flame, all appear to him to be of the same brilliancy. He will then find that while the planet is redder than the electric light, it is bluer than the candle flame, and is, in fact, very nearly half way between the two in color. If either source of light is made brighter than the other, its tendency is to appear whiter.

During the last opposition, sixty paintings were made of the planet, with the 12-inch Harvard refractor, and sixty-six uncolored drawings. They were all constructed upon a uniform scale of $\frac{1}{200000000}$, the planet being represented by a disc, 34 millimeters in diameter. Usually powers of 200 to 400 were employed. It was found that in the evening, the most prominent and striking color of the planet could be represented very well by carmine. It was also found that it could be equally well represented by golden yellow. When painted in the day-time it was orange, with more or less carmine, depending on various circumstances. If a high power was used it was much redder than with a low power. All of these changes may be readily explained by the elementary principles of Physics, but they illustrate very well some of the difficulties that were presented by the

* Communicated by the author.

research. As the planet is illuminated by sunlight, it is evident that in order to obtain a correct result, the pigment used to represent it should be illuminated by the same source. The paintings should, therefore, be made in the day-time.

Experiments were also made in a darkened room, the only light transmitted being through a small round hole bored in the shutter. Various pieces of colored stone were placed upon a mirror, which reflected the light of the sky into the room. Reflections of these stones were then viewed in two pieces of flat glass, supported inside the room. By varying the angles of the glasses, the intensity of the sunlight reflected from the stones could be varied, so as to render them either brighter or fainter than the planet, as seen in the telescope. Paintings of the planet, illuminated by the same light as that used in the evening, were then compared with the light from the stones.

The other shutters of the room were then opened, and the paintings illuminated by daylight. It was found that the same laws of color held good with the stones that had been previously found applicable to the planet. The various stones tried were a piece of brown lava from Vesuvius, a piece of red basalt, a piece of brown sandstone, a piece of very red granite, and two pieces of brick, one an orange red, and the other the color of dragon's blood. The former may be best represented by dragon's blood with a little Saturn red in it. The red granite, which is half way in color between the two pieces of brick, is well represented by dragon's blood and sienna, half and half. It was found that this piece of granite under suitable illumination could be made to match exactly any of the paintings of the planet. As its color was not far from that of an average brick, our next experiment was to select a distant building made of brick of the proper color, and make a painting of it as seen in the telescope. This painting was necessarily made by daylight, and another telescope had to be used, as the building was not visible from the dome of the 12-inch. The building selected was two and a half miles distant. The telescope employed was a 6-inch refractor by Clacey. The result was as anticipated, that when the painting of the building was compared with some of the daylight paintings of Mars, the colors were identical. In each case the colors were separately mixed at the time, although the components were the same, and in each case the result exactly satisfied the eye.

The reason that a red planet or distant brick building can be matched by daylight with an orange pigment is because of the bluish white light reflected from the atmosphere, lying between

the distant object and the eye, which is mixed with the red light coming from the object, changing it from red to orange. If the brick is examined close at hand, a red pigment must be employed to represent it. When the planet is viewed at night, or when a piece of brick near at hand is illuminated by sunlight, but the pigment is illuminated by a yellow artificial light, this light by enforcing the red components of the pigment, and absorbing the blue, makes the pigment really appear red, and therefore match the Sun-illumined object. The object, therefore, although painted yellow by night, really appears to the eye redder than when painted orange by daylight. This fact was well brought out by an experiment made at night, employing the magnesium light instead of the oil lamp as a source of illumination for the pigment. In that case the color best matching the planet was found to be dragon's blood which, as we have seen before, is probably not far from its true color, which we considered to be the same as the red granite, and therefore to be represented by equal parts of dragon's blood and sienna.

But red is by no means the only color visible upon the planet. When near the limb, the reds always appear yellowish, indicating probably an atmospheric absorption of the red portion of the spectrum, an effect quite at variance with the action of our own atmosphere, which tends to absorb the blue rays.

Next to the reds and yellows, the most important colors are the grays and greens. The latter colors one would actually at first attribute to an optical illusion, due to contrast with the prevailing tint. If this were the case, however, these portions of the planet should be painted blue, blue being the complementary color of the orange seen by daylight. Blue pigment seen by lamp light becomes green, which is the complementary of the red seen at night. Therefore in either case blue would be the complementary color and not green. Experiments under both of these conditions, however, made upon several occasions, conclusively showed that these greens could not be matched by blue pigment of any tint, but were a true and genuine green. Although rare, yet upon four occasions it was noted that green was the most conspicuous color visible. This was due sometimes to its covering a large area, and sometimes to its being a more intense color than the red. This also indicated that the green could not be due to contrast. It was found by experiment that the effect upon green pigment produced by using an artificial illumination was very much less marked than upon red, the only effect being, that when so illuminated, it appeared rather more yellow than when seen by

daylight. This would imply that the greens upon Mars were in reality slightly more yellowish than the evening paintings would indicate.

When the seeing became bad the greens and reds united to give a whitish tint, and the colors disappeared. This further indicated that the greens were not due to contrast. A piece of black paper was introduced into the field of view of the telescope, cutting off the red, but the green color remained unchanged. An examination was made of Jupiter, the disc being a bright yellow, but no green could be detected upon it. The greens, especially the light greens, usually appeared near the poles, which were necessarily near the edge of the disc, but on these occasions a region near the center was seen of a light green color. The green could not therefore be attributed to the secondary spectrum of the glass. Moreover, the telescope was thrown alternately slightly in and out of focus, changing the color of the outside fringe of light, but without altering the green hue upon the disc.

The green was not due to atmospheric refraction since it was seen near both poles, besides which the color due to this cause is easily overbalanced by that due to the lack of achromatism in the eyepiece when the planet is placed near the edge of the field. The green is not due to an optical illusion caused by the brightness of the snow. It is sometimes seen between the snow and the red regions of the planet, and is also seen when the snow is not visible. Indeed I think it has been often mistaken for the snow, as it is a much larger and more conspicuous object. The real snow is much more difficult to see than is generally supposed, and is frequently not visible at all. I have only seen it occasionally when it was readily distinguished by its extreme brightness and whiteness. An excellent idea of its appearance is given in Chambers' Astronomy, fourth edition, and I have seldom seen it of much greater extent. The drawing is by Green, and like all of his work upon Mars, is most accurate and life-like. The gray objects upon Mars, when the seeing was fine, acquired a slightly yellowish, and in the day-time a brownish tint, owing to their confusion with the surrounding regions, but when the seeing was good, they were either a pure gray, or of a slightly greenish color. This does not apply to all the darker regions, as we shall see later. There was no difficulty in obtaining distant green terrestrial objects to study through the telescope, and it was found that even upon very clear days, when over two or three miles distant, they appeared either gray or greenish gray. This was particularly true of the darker shades. In fact I never

at any time saw any colors as brilliant as the bright greens upon Mars. Even when a piece of bright red paper was introduced into the field of the telescope, no appreciable contrast effect was produced upon the terrestrial greens. This fact, together with the other that the greens on Mars were seldom seen by daylight, make me think that those seen upon the planet must be due to some illusion, whose origin had not as yet been eliminated, for one cannot well conceive of more vivid greens than those due to some of our own vegetation. I had been observing a tree some two and a half miles distant with the telescope one very clear evening, when I noticed that there was an electric lamp just by the side of it. That evening I pointed the telescope again on the tree, and it instantly shone out a most brilliant bluish green, fully equalling in intensity anything I had seen upon the planet, and a trifle bluer. This explained why it was that in the day-time I had only detected the greens upon Mars with difficulty while at night they were conspicuously visible,—the white light reflected by our own atmosphere had corrected them into grays.

Numerous observations were made of the colors of particular regions, especially of those which appeared very dark in tint. Attempts were also made to determine the color of the canals. This latter is an extremely difficult undertaking, as the smaller the area, the harder it is to assign any particular color to it. The apparent area of any very small region always strongly affects one's judgement of its color, and in comparing two colors, it is most important that their apparent areas should be equal. Regarding the colors of these smaller regions, as it is very desirable that the opinions of others be formed independently of my own, I will defer describing them until another paper, merely stating that there is some evidence that certain regions do not seem to remain at all times of the same color.

In closing, I shall mention that these colors have been seen through three different telescopes, 12-inch and 15-inch at Cambridge, and more recently through the 13-inch telescope at Arequipa. The latter instrument brought them out very finely, the greens showing well even in the day-time. On April 5, I could see the great canal north of the Sinus Magnus with a power of 810 diameters. It will be noted that in what precedes I have carefully abstained from advocating any hypothesis regarding the true sources of any of the colors, merely confining myself strictly to a statement of the observed facts.

AREQUIPA, PERU, March 7, 1892.

THE TOTAL SOLAR ECLIPSE APRIL 15-16, 1893.*

H. S. PRITCHETT.

The total eclipse of the Sun which will occur in April, 1893, is the last in the present century which is likely to add to our knowledge of solar physics. Although the duration of totality is not so great as that which characterizes the two remarkable series to which the eclipses 1883 and 1886 belonged, it is quite large, amounting to $4^m\ 46^s$ at the maximum.

Not only is this eclipse valuable for its long duration, but observations of it are particularly desirable for two reasons.

In the first place the path of the shadow-cone on the Earth's surface is such that it permits observations widely separate in distance and time. Photographs of the corona taken in Chile will precede by some 3½ hours those taken on the west coast of Africa, Probably no observations could be made which are more likely to help in the solution of pending problems, or will afford more trustworthy data concerning the nature and behavior of the matter about the Sun than two photographs of the corona, the one taken in Chile or the Argentine Republic and the other in Africa. These should be strictly comparable.

An additional strong incentive for observation is found in the fact that the eclipse of 1893 takes place as a sun-spot maximum is approaching, and would therefore afford most interesting results for comparison with the mass of observations gathered in the two eclipses of 1889, occurring near a sunspot minimum.

Professor Holden has announced that the Lick Observatory will send a party to Chile under the direction of Mr. Schaeberle. The Harvard Observatory party already in Peru, under the direction of Professor W. H. Pickering, will, it is understood make complete photographic and spectroscopic studies of the corona from some point in Chile. It is therefore extremely important that the remaining points of observation should be manned.

I have endeavored to collect in the following memoranda such information as is accessible concerning the means of transit to available stations, and the meteorological conditions of the stations themselves.

After leaving Chile the track of the shadow lies across the northern part of the Argentine Republic and passes entirely across Brazil. In this entire region there seem to be but two available points, one in the Argentine Republic on the railroad

* Communicated by the author.

which runs up from Buenos Ayres, and the other in the province of Ceara in Brazil. The next available points for observation are on the African coast. The following table contains a list of such stations as are likely to be available.

Station.	Long.	Lat.	Beginning Totality. Local Time.	Duration Totality.
	° ′	° ′	h m	m s
Rosario de la Frontera Arg. Rep.	65 07	25 48 *S*	Apr. 15, 20 40	3 8
Para Curù, Brazil.....	38 30	3 42 *S*	Apr. 15, 23 40	4 44
Island of Goree.....	17 16.7	14 39.9	northern limit of shadow.	
Portudal, Senegal.....	16 49	14 23		
Joal, Senegal.	16 37	14 09	Apr. 16, 2 29	4 9

Rosario de la Frontera, in the Province of Salta, is a small town on the railroad which runs from Buenos Ayres to Jujuy. It is therefore easily acessible, and the expense of a party in reaching it would not be large. The distance from Buenos Ayres is some 600 miles.

The town lies almost exactly on the line of central eclipse. It has an altitude of 800 metres, and although the cloudy season will have commenced, the probabilities for clear weather in the forenoon seem good. The nearest point for which meteorological data are accessible is Salta, distant 80 miles. At this point the mean annual temperature is 63°.6 F. and the annual rainfall is 22.8 in., and the probability for clear weather at this season is estimated to be two-thirds. It seems extremely desirable that this station should be occupied. Observations at the eastern end of the shadow track are likely to be more numerous than at the west end, and for this reason it is desirable to increase the chances at the west end. There is a direct line to Buenos Ayres from New York, and this station is therefore easily reached.

Para Curù Brazil, is quite near Forteleza, a city of some 20,000 inhabitants and the capitol of the Province of Ceara, and lies almost exactly on the line of central eclipse.

It is also said that it would not be difficult to reach a point in the interior at a higher elevation. M. Cruls, Director of the Observatory of Rio Janeiro, proposes to collect full meteorological data at Forteleza during April, 1892, for guidance of observers in choosing points of observation for this eclipse. It must be said, however, that the chances for clear weather near Forteleza seem poor indeed. The annual rainfall here is something over 100 in., and from the best attainable data the average rainfall during April for five years past, including 1891, has been 10 in., and the average number of rainy days in April during the same period has been 15, and has been as high as 21 in one year.

The probability of cloudiness is stated by M. Cruls to be about two-thirds.

In spite of all this, however, taking into account the altitude of the Sun and the duration of totality, it may seem desirable to occupy a station in the region near Forteleza.

After leaving South America no points for observation present themselves till one reaches the African coast.

The Island of Goree, which lies some five miles off the coast and forms the protection to the harbor of Dakàr seems to be the natural outfitting point for any parties destined to the Senegambiam coast. Goree is a point of great importance as a military and commercial post. The island, which is rocky and precipitous, is some forty acres in extent. A French garrison is kept here, and it is a coaling station for the French Navy, and is reached by steamers from Liverpool and Bordeaux. Sailing vessels from New York in the Senegambian trade make this a rendezvous.

The climate is described as most excellent and somewhat cooler than that of the neighboring mainland. Clear weather at this season is almost a certainty. A rainy day in April has never been recorded. The rainy season sets in about the middle of June.

Between Goree and the neighboring points on the coast there is almost daily communication by sailing vessels and small steamers, and unquestionably the French government would afford all needed assistance to observers.

With Goree as a base of operations there is apparently no difficulty in locating observing parties at either Portudal or Joal, the latter of which lies almost exactly in the line of central eclipse. There is a considerable discrepancy in the published values of the geographical position of Goree. The value given, taken from the *Annuaire de Senegal*, is presumably correct, as longitude and latitude are there given to the nearest second of arc. The other points in Senegal whose positions are mentioned have been referred to Goree.

The temperature seems quite tolerable, the average being about 70° Fahr.

From what has been stated, and considering Chile as already well occupied, there would seem to be but three points for remaining American expeditions to choose from. These are the regions near Rosario de la Frontera, Argentine Republic; Forteleza, Brazil; and either Joal or Portudal on the Senegambian coast.

In case any stations are to be occupied by American parties, it is exceedingly desirable that there should be an effective coöperation between such parties, both in choice of stations and in the arrangement of work. In the work of eclipse observations during the past there has been a serious absence of any attempt at a coördination of work, and very little effort to make the work of different observers comparable. It is with the hope that some such coöperation may be secured that attention is called to the matter at the present time.

It may be added that ambitious travelers who care to brave desert will find a favorable observing station on the caravan route just north of Timbuktu.

I am indebted to Professor Corti of San Juan, Arg. Rep., for maps and meteorological data concerning the province of Salta, and to Mr. John M. Sherwood, formerly of Goree, for similar data concerning Senegambian points.

EXPLANATION OF THE MYSTERY OF THE EGYPTIAN PHŒNIX.*

T. J. J. SEE, BERLIN.

The beautiful Egyptian fable of the Phœnix enjoyed great popularity among the ancients, and the mere fame of the legend renders the accounts left us by the Greeks and Romans necessarily somewhat inconsistent, on account of the distortions which it suffered from different writers; the gist of the mystery is, however, condensed in the following statements:—

The Phœnix was a miraculous bird of Arabian origin, the only one of its kind in the world, adorned with golden and red plumage, and in form resembling an eagle; it was sacred to the Sun and appeared at the Temple of Heliopolis at long intervals of time; when of a very great age it built a nest of twigs and branches, ignited it with fire, forthwith lighted upon the funeral pyre and was consumed to ashes, from the glowing embers of which the new Phœnix at once triumphantly arose.

The true explanation of the mystery of this acknowledged symbolism is a matter on which not even Egyptologists have ever been agreed; but since the story of the Phœnix seems to hinge upon astronomical phenomena, we may perhaps venture to offer an hypothesis which has presented itself in connection with the investigation of the ancient color of Sirius, and seems exceedingly probable.

* Communicated by the author.

Of all the authorities who have left us accounts of the Phœnix none are perhaps more trustworthy than Tacitus, who speaks of the bird Phœnix coming in Egypt after a long course of ages during the consulship of Palus Fabius and Lucius Vitellius (34 A. D.). After noticing the miraculous reports of the bird, and briefly describing it, the historian adds that it was sacred to the Sun, and continues :—

"De numero annorum varia traduntur. Maxime vulgatum quingentorum spatium: sunt qui asseverent mille quadringentos sexaginta unum interjici, prioresque alites Sesostride primum, post Amaside dominantibus, dein Ptolemæo qui ex Macedonibus tertius regnavit, in civitatem cui Heliopolis nomen advolavisse, multo ceterarum volucrum comitatu novam faciem mirantium. Sed antiquitas quidem obscura: inter Ptolemæum ac Tiberium minus ducenti quinquaginta anni fuerunt. Unde nonnulli falsum hunc Phœnicem neque Arabum e terris credidere, nihilque usurpavisse ex his, quæ vetus memoria firmavit."

(Annalium, Lib. VI., Cap. 28.)

Tacitus therefore says the Phœnix is vulgarly reported to live 500 years, but there are some (and he appears to imply that these are the "select few," the "learned ones," perhaps the Egyptian priests) who positively affirm that the miraculous bird lives 1461 years. This is the length of the Sothic Period, and such a coincidence in length of time cannot be the result of chance. Therefore a strong presumption is at once raised in favor of the idea that the Phœnix is a symbolization of the Dog Star Period. The Egyptian year, as is well known, consisted of 365 days, and consequently the calendar annually fell short of the Julian or natural year one fourth of a day; this annual difference would accumulate, and in 1461 Egyptian years amount to a whole year, so that the cycle would begin anew. This great cycle is what is known as the Sothic Period, which began when the first of Thoth (the first month of the Egyptian calendar) coincided with the heliacal rising of Sirius. This phenomenon of the Sun and the Dog Star rising together took place on the 20th of July, and marked the beginning of the inundation of the Nile.

In the preceding investigation* we have shown that Sirius was anciently fiery red, and this color will now enable us to explain not only the gorgeous plumage of the Phœnix (mentioned by

* See April and May numbers of ASTRONOMY AND ASTRO-PHYSICS.

Herodotus and Pliny), but also how the old Phœnix was mystically spoken of as consuming itself with self-ignited fire and the new bird arising from the glowing ashes. For the colors of the Phœnix were merely the hues of the golden Sun and of the ruddy Sirius. And the old Phœnix cycle closed its long career when the first of Thoth came round to the day of the fixed year (July 20) on which Sirius and the Sun rose together, and the new Sothic or Phœnix cycle began on the same day. Therefore, since the beginning and end of the Sothic Period was determined by the heliacal rising of Sirius, and that star was fiery red, it is easy to see why the priests represented the old Phœnix as consuming itself with self-ignited fire (of the Dog Star) at self-appointed time, and the new Phœnix as arising immediately from the ashes of the old. The "burning up" of the Phœnix therefore represents merely the "burning" of the ruddy Sirius, to which may perhaps be added the flames of the morning glow through which the priests observed the star coming with the rising Sun.

Since the Sothic Period was determined by observations of the heliacal rising of Sirius made at the Heliopolitan Temple of the Sun, we can readily understand why the Phœnix was spoken of as coming from Arabia, which lay to the east, in the direction of the expected phenomenon. The Phœnix being a symbolization of the Sothic cycle, there could of course be only one such "bird" in the world; and since the period extended over ages, it is easy to conceive how a very little mystic or even poetic fancy would enable the priests to represent it as a bird endowed with swift wings symbolic of the flight of time. The Sothic Period being reckoned from the heliacal rising of Sirius, it is also plain why the bird was sacred to the Sun, and why it appeared to the priests at the Heliopolis by whom the observations were made. Lastly, since the cycle repeats itself in endless succession, its duration is everlasting, and hence the secret of the immortality of the Phœnix.

The only point that needs further elucidation is the period. Tacitus relates that the first Phœnix appeared in the reign of Rameses II. (who was called by the Greeks Sesostris); and we learn from Censorinus that a Sothic Period was completed A. D. 139; therefore that Period must have begun B. C. 1322.

This epoch falls within the limits of the various dates assigned to the reign of Rameses by different chronologists—dates which hinge mainly upon different interpretations of the somewhat uncertain dynastic successions recorded in the fragments of Manetho's History preserved by Josephus—and agrees perfectly

with the time assigned to Rameses II. by Sir Gardner Wilkinson. Tacitus also relates that a Phœnix appeared in the reign of Amasis (B. C. 564-526), and another in the time of Ptolemy III. Euergetes I. (B. C. 247-222), and finally in the year 34 A. D. Now it is evident that the periods here mentioned are very unequal and can not be reconciled to any fixed interval. Tacitus does not hesitate to question the genuineness of the last Phœnix, and we know from other authorities that a Phœnix exhibited at Rome during the celebration of the secular games in the year of the City 800 (A. D. 46) was in like manner an imposture. Therefore, since the period seems to be 1461 years, we may venture to suggest that none of the Phœnixes reported by Tacitus are really genuine except the first, which appeared under the reign of the Great Rameses. The interval of 1461 years, however, is so very long that only one in a great many generations could ever hope to witness the celebration of its completion; therefore it is likely that certain kings ambitious to glorify their reigns would occasionally celebrate the completion of some numerical part of the Sothic or Phœnix period, and proclaim as a special sign from Heaven the coming of the sacred Phœnix. All the Phœnixes reported by Tacitus (except that of 34 A. D., when Egypt was under Roman sway) appeared in the reigns of very powerful kings, and this circumstance adds decided plausibility to the suggestion just advanced, which seems indeed the only reasonable explanation of the irregular intervals.

It is therefore probable that the story of the Phoenix was devised at the beginning of the new Sothic Period in the reign of Rameses the Great, and proclaimed by the learned hierarchy in mystic symbolisms to the common people. This king was a great patron of art and science, and the institution of the sacred Phœnix as a new religious symbolism to mark the beginning of a great epoch extending over centuries is in keeping with the ambitious designs of his victorious reign.

Therefore, since Sirius was in antiquity fiery red, the Sothic Period explains in a particularly happy manner all the essential characteristics of the mysterious Phœnix—its great age and solitariness in the world; its color and sacredness to the Sun; how it burns itself up and the new bird arises from the glowing ashes; its Arabian origin and appearance at Heliopolis; lastly, why the symbolization assumed the form of a bird; and hence it seems to me that the theory here advanced ought to have some claim to acceptance, particularly since all the theories which I have hitherto read fail signally to explain why the symbolism

took the form of a bird with swift wings, how it consumes and regenerates itself, and the very great age to which it attains.

If the theory here advanced be true, the legend of the Phœnix in turn adds to the certainty of the ancient redness of Sirius, which was therefore red not only in the time of Homer, but also in the time of Rameses; and probably from the very dawn of the ancient Egyptian civilization.

There is perhaps no more typical example of the mysticism characteristic of Egyptian learning under the Pharoes than that furnished by the marvelous story of the Phœnix—certainly the most wonderful and mysteriously beautiful of all the charming myths that have descended to us from the poetic lore of the early ages.

ROYAL OBSERVATORY, Berlin, Jan. 28th, 1892.

OBSERVATIONS OF NOVA AURIGÆ AT VASSAR COLLEGE OBSERVATORY.*

M. W. WHITNEY.

A series of comparisons in magnitude between Nova Aurigæ and neighboring stars was carried on by myself and my students during the interval from Feb. 9th to April 6th. On this last date, in the prevailing moonlight, the star was no longer visible in our twelve inch telescope. Our method of comparison was Argelander's, with the modification of that method suggested by Professor Pickering. In most cases, the magnitudes of the table given below are the means of two or more independent determinations.

The magnitudes of the comparison stars were taken from the Harvard Photometry, until the Nova fell below the limit of that Catalogue. After that time the magnitudes adopted were those of the Durchmusterung, except in the cases of DM 30°935 and 30°937, where there was an evident difference of magnitude between two stars, both of which were estimated at 9.3 in the Bonn Catalogue.

The following are the comparison stars:

χ Aurigæ	DM 29° 911
ϕ Aurigæ	29° 923
σ Aurigæ	30° 913
H. P. 983	30° 894
" 1033	30° 935
" 956	30° 937
" 969	30° 914

u of Professor Pickering's list

ASTRONOMY AND ASTRO-PHYSICS, March No.

* Communicated by the author.

Eastern Stand.	Time. h	Est. Mag.	Instrument.	
Feb. 9	10.5	5.26	Opera Glass	Moonlight
13	8.6	5.29	"	"
15	9.6	5.42	"	
16	8.7	5.33	"	
18	9.2	5.40	"	
23	7.7	5.75	"	
	10.0	5.72	"	
26	8.6	5.68	"	
27	9.3	5.62	"	
Mar. 3	9.7	5.71	"	Moonlight
4	10.0	5.84	"	"
9	11.0	Barely seen	"	"
10	9.5	{Not seen {star, mag. 6.4 seen	"	"
11	10.2	7.7	3-inch glass	"
13	8.5	7.8	"	"
14	9.6	7.9	"	"
15	7.7	8.5	12-inch glass	
16	9.3	8.6	"	
20	8.3	9.3	"	
21	9.4	9.5	"	
24	9.6	$= u$	"	
26	8.3	$= u + 0^m.1$	"	
April 6		Not seen	"	Moonlight

VASSAR COLLEGE OBSERVATORY, April 26, 1892.

PRELIMINARY ADDRESS OF THE GENERAL COMMITTEE OF THE WORLD'S CONGRESS AUXILIARY ON MATHEMATICS AND ASTRONOMY.*

GEORGE W. HOUGH, LL. D., CHAIRMAN.

The World's Congress Auxiliary is an Organization maintained by the World's Columbian Exposition, and approved by the Government of the United States, for the purpose of organizing a series of Congresses or Conventions to be held during the progress of the Exposition in 1893, and which will bring together the leading scholars of the world for the mutual interchange of ideas on topics bearing on human progress.

A Scientific Congress, to present and consider investigations in its special lines of research from all parts of the world, cannot fail to exert an important influence in the progress of scientific development. The personal interchange of views in regard to methods of observation and investigation will undoubtedly be productive of mutual benefit to the members of the Congress, as well as of lasting value to science.

The General Committee on Mathematics and Astronomy presents this preliminary address, cordially inviting the coöpera-

* Communicated by the author.

tion of all persons and societies interested in the department of physical science.

As the matter assigned to this Committee covers a large field in physical science, it has been thought advisable to arrange the subjects to be considered under the following chapters and sections, in which in consideration of its recent development and growing importance, Astro-Physics has been assigned a separate chapter from other branches of general Astronomy.

The following are some of the topics suggested for consideration under the several chapters:

CHAPTER I.—PURE MATHEMATICS.

Section a. History and Bibliography.
Section b. Arithmetic and Theory of numbers.
Section c. Analysis.
Section d. Geometry.
Section e. Analytical Mechanics.
Section f. Mathematical Physics.

CHAPTER II.—ASTRONOMY.

Section a. History of Astronomy.
Section b. Astronomical Instruments.
Section c. Methods of Observation.
Section d. Physical Astronomy.
Section e. Observatory Buildings.

CHAPTER III.—ASTRO-PHYSICS.

Section a. Spectrum Analysis.
Section b. Astronomical Photography.
Section c. Stellar Photometry.

The object of this preliminary address is simply to bring the subject of the Congress to the notice of the scientific men of the world for advice and suggestions as to the general conduct of the convention, and in particular as to the scientific questions to be discussed. Recommendations of themes to be discussed and of persons to present them are especially solicited from the members of the Advisory Council of the Astronomical Congress. The Advisory Councils constitute the non-resident branches of the Auxiliary Committees. Additions to these councils will be made from time to time. Communications may be addressed to the chairman of the general committee, or to the chairman of the proper special committee.

It is expected that men eminent in special lines of research will be invited to furnish papers on the leading topics under consider-

ation. The suggestions and recommendations invited will be used in the formation of the programme for the Congress.

The chairmen of the special committees of the several chapters under the charge of the general committee, are as follows:

On Pure Mathematics:

PROFESSOR E. H. MOORE, Chicago University, Chicago, Ill.

On Astronomy:

PROFESSOR G. W. HOUGH, Dearborn Observatory, Northwestern University, Evanston, Ill.

On Astro-Physics:

PROFESSOR GEO. E. HALE, Kenwood Astro-Physical Observatory, Chicago, Ill.

GEORGE W. HOUGH, *Chairman.*
ELIAS COLBERT, *Vice-Chairman.*

E. H. MOORE,	R.W. PIKE,
GEORGE E. HALE,	GEO. C. COMSTOCK,
G. A. DOUGLAS,	W. W. PAYNE,
MALCOLM MCNEILL,	

Committee of the World's Congress Auxiliary on a Congress of Mathematicians and Astronomers.

NEW BINARY STAR β 208.*

S. W. BURNHAM.

On March 12, 1874, when observing with the 6-inch refractor, I found that the sixth magnitude star in Argo, Lalande 17103, was a moderately close double star. The components were estimated as 6 and 9 magnitude, and the distance about 1″.4. It was a very fine object with that instrument, and not difficult for a new pair. Since that time it has been sufficiently often measured to show that the components have considerable relative motion, and that they must form a binary system. Indeed it hardly needed any observations with the micrometer to demonstrate this fact. Since the well-known proper motion of this star made it practically certain that the two components were moving together, or it would have been discovered before. As a single star it has an annual proper motion of 0″.466 in the direction of 331°.7, and with one star fixed in space, it would have formed a wide and easy pair at any time before 1870, and could not have escaped detection.

* Communicated by the author.

The following are all the measures down to this time:

	°	′				
1874.19	30.4	1.4	±	6.0.....9.0	β	1n
1877.13	31.7	1.71		6.0.....9.0	Cin.	1n
1878.43	33.9	1.37		6.0.....8.0	Cin.	5n
1882.21	40.9	1.21		6.0.....9.0	Sp	3n
1886.18	43.2	1.27		6.0.....8.0	Wilson	1n
1889.15	47.5	1.06		7.0.....8.0	β	2n
1892.11	52.3	0.70		6.8.....8.1	β	3n

It will be seen from these measures that the distance is now rapidly decreasing, and that it may soon become a very difficult pair. The angular motion will doubtless be rapid for some time to come, and the period cannot be very long. For the present at least it should be measured each year.

The place of this pair (1880) is:

R. A. $8^h\ 33^m\ 54^s$
Decl. $-22°\ 16'$

MT. HAMILTON, April 20, 1892.

---

52 HERCULIS (β 627).*

S. W. BURNHAM.

A recent set of measures of this pair seems to show that the companion has a slow direct motion about the primary. The distance is too large to look for any rapid movement, but there is hardly any doubt of their forming a physical system. Although this is an easy pair to measure, there are but few observations. It was discovered with the Chicago 18½-inch, but can be well seen with a much smaller aperture.

The following are all the measures:

	°	′			
1878.38	309.4	1.83	5 .....10.5	Burnham	5n
1881.42	306.6	1.76	5 10	Bigourdan	1n
1886.33	307.6	2.03	5.1..... 9.5	Engelmann	8n
1892.24	318.7	1.62	5 ..... 9.1	Burnham	3n

Bigourdan measures two 12m stars:

1881.42	228°.6	67″.01	1n
1881.42	267 .6	143 .15	1n

These distant stars have not been measured previously.

MT. HAMILTON, April 20, 1892.

* Communicated by the author.

XUM

ORBIT OF β 612.

(*Letter from Prof. S. Glasenapp to S. W. Burnham.*)

OBSERVATOIRE DE L'UNIVERSITÉ IMPERIALE,
St. Petersburg, April 12, 1892.

DEAR SIR: You have had the kindness to communicate to me all the measures (published and unpublished) of the double star β 612 which you discovered in 1878. The following are the measures obtained by the four astronomers, Burnham (β), Hall (Hl), Schiaparelli (Sp) and Engelmann (En):

	°	″	
1878.33	56.1	0.23	β 3n
1878.96	60.5	0.24	Hl 4n
1884.02	52.4	0.28	En 5n
1889.46	166.8	0.3	Sp 3n
1890.39	179.7	0.3	Sp 2n
1891.28	191.1	0.28	β 3n
1891.44	191.1	0.32	Hl 3n
1891.48	186.1	0.2	Sp 1n
1892.12	198.7	0.35	β 1n

To obtain normal positions, we form simple arithmetical means for 1878 and 1891:

	°	″	
1878.65	58.3	0.23	2 observers.
1884.02	52.4	0.28	1 observer.
1889.46	166.8	0.3	1 "
1890.39	179.7	0.3	1 "
1891.40	189.4	0.27	3 observers.
1892.12	198.7	0.35	1 observer.

One of the first two positions is evidently erroneous. The first is derived from the measures of Burnham and Hall made on seven nights with large telescopes. The second position is the result of measures of one observer, the late Dr. Engelmann, made on five nights with a relatively small telescope. The measures of Burnham and Hall agree substantially, and therefore it seems probable that the position for 1878 is correct, and that there is considerable systematic or personal error in the position of Engelmann.

Rejecting the observations of Engelmann in 1884, we obtain by the graphical method, which I proposed several years ago, the following approximate elements:

$$
\begin{aligned}
T &= 1870.04 \\
U &= \quad 38.64 \text{ years.} \\
\eta &= +9.32^{\circ} \\
\Omega &= 314.1^{\circ} \\
i &= \quad 17.0^{\circ} \\
\lambda &= \quad 31.6^{\circ} \\
e &= \quad 0.13 \\
a &= \quad 0.28''
\end{aligned}
$$

We then find the corrections of η, T, Ω and i, namely: $dT = +3.97$ years; $d\eta = +2°.68$; $d\Omega = +3°.2$; $di = +6°.0$. Finally the elements have the following values:

$$\begin{aligned} T &= 1874.01 \\ U &= 30.00 \text{ years.} \\ \eta &= 12.00° \\ \Omega &= 317.3° \\ i &= 23.0° \\ \lambda &= 31.6° \\ e &= 0.13 \\ a &= 0.28'' \end{aligned}$$

The agreement of these elements with the observations is very satisfactory:

t	θ_o	θ_c	$\theta_o - \theta_c$	P_o	P_c	$P_o - P_c$
1878.65	58.3	58.9	− 0.6	0.23	0.24	− 0.01
1889.46	166.8	170.9	− 4.1	0.3	0.31	− 0.01
1890.39	179.7	170.4	+ 0.3	0.3	0.31	− 0.01
1891.40	189.4	189.1	+ 0.3	0.27	0.30	− 0.03
1892.12	198.7	196.2	+ 2.5	0.35	0.29	+ 0.06

The error of Engelmann's measure in 1884 is about 60° in the angle of position.

The element λ is probably uncertain because the eccentricity of the true orbit is small, but it will be possible to find its correction after the periastron passage which will occur in 1908.

From your catalogue I take the position of this star for 1880:

$$\begin{aligned} \beta\,612 &= \text{B.A.C. } 4559 \\ \alpha &= 13^h\,33^m\,40^s \\ \delta &= +11°\,21' \end{aligned}$$

Very truly yours,

S. GLASENAPP.

NOTE. In the foregoing orbit by Professor Glasenapp the position for 1892.12 is from my first measure in the early part of the present year. Subsequently I completed a set of measures by observing it on two other nights. Professor Glasenapp, however, had not received the complete measures when he computed the orbit. The mean of the three measures is:

1892.14 198°.7 0″.31

It will be seen that this is identical in angle with the first observation, and differs so little in the distance that the substitution could not materially affect the elements of the orbit given above. S. W. B.

NOTES FROM THE TIME SERVICE OF THE WASHBURN OBSERVATORY.*

S. D. TOWNLEY.

In the time service of the Washburn Observatory, three sidereal chronometers are compared each morning with the standard

* Communicated by the author.

mean time clock, and as a check upon these comparisons it has been my habit to make a direct comparison of each of the chronometers with the standard sidereal clock.

The two standard clocks are compared also, so that if the direct and indirect comparisons of any chronometer were absolutely exact the resulting corrections to the chronometer would be identical.

Out of curiosity to see what accuracy could be attained in direct comparisons I have taken *all* the chronometer comparisons from 1892, Jan. 1, to 1892, March 11 (213 in all), and computed a probable error.

Taking the differences, without regard to signs, between the direct and indirect comparisons as residuals I find a probable error of $\pm$ 0^s.027. Assuming the probable error of an indirect comparison to be $\pm$ 0^s.010 then the probable error of a direct comparison of a sidereal chronometer beating half seconds with a sidereal clock beating seconds is $\pm$ 0^s.025,

$$(r^2 = \overline{0.027^2} - \overline{0.010^2}).$$

I have computed the probable error for each chronometer separately and find that the Tobias chronometer, which has a very clear beat, gives the smallest probable error, $\pm$ 0^s.021, while the other two Bliss chronometers give $\pm$ 0^s.024 and $\pm$ 0^s.031. Taking into account the signs of the residuals, $I - D$, I find that the negative residuals predominate with each chronometer and for the mean of the 213 observations $I - D = -$ 0^s.006 $\pm$ 0^s.002. Applying this correction to the residuals would reduce the probable error of a direct comparison as computed above, but not appreciably. Of these 213 residuals two are 0^s.10, six are 0^s.09 and all the rest are smaller.

In making the comparisons I estimate the fraction of a second to the nearest 0.05 and if the difference between direct and indirect comparisons is ever more than one-tenth of a second, I know immediately that something is wrong in the reduction.

I have had nearly three years practice at this work and about twenty-five seconds is the time necessary for making a comparison.

Having noticed a reference, Chauvenet, Vol. II, page 193, to Professor Peirce's discussion of an observer's personal scale, I thought to investigate my time observations to see if any such scale existed. The observations are made with a three-inch Fauth transit, magnifying power of 115, eye-and-ear method, chronometer beating half seconds. I estimate the *time* of tran-

sit of the star, not the space passed over, to the nearest tenth of a second.

Theoretically, in a large number of observations, there should be as many transits on any one-tenth of a second as upon any other tenth. Upon investigation, however, I found this to be quite far from the truth. From 188 observations of stars of declinations from + 20° to + 65° there was a decided preference for the 0 and 5 tenths, and a decided neglect of the 4 and 8 tenths. It is easy enough to see why an observer should favor the 0 and 5 tenths, but I am at a total loss to know why the 4 and 8 tenths should be neglected rather than the other tenths. Feeling sure that such large discrepancies should not occur, I determined to watch myself in the future. A second series of 816 transits was obtained which are much more evenly distributed, but still there is a tendency to neglect the 4 and the 8 tenths.

The following table will show the results of these series.

	EYE AND EAR.				CHRONOGRAPH.	
	Series I.		Series II.		Series III.	
Tenth.	No. of Transits.	Per cent.	No. of Transits.	Per cent.	No. of Transits.	Per cent.
0	47	25.0	109	13.4	25	11.8
1	18	9.6	85	10.4	23	10.9
2	23	12.2	93	11.4	17	8.1
3	14	7.4	98	12.0	22	10.5
4	8	4.3	71	8.8	15	7.1
5	26	13.8	76	9.3	22	10.5
6	23	12.2	79	9.7	19	9.0
7	12	6.4	71	8.8	20	9.5
8	5	2.7	64	7.9	18	8.5
9	12	6.4	70	8.6	30	14.2
Totals	188	100.0	816	100.3	211	100.1

In Series II, there seems to be a tendency to put the transit in the first half of the second, and the 8 is still the most neglected digit. Why this particular figure should be neglected, I am unable to say, unless it is perhaps that this is the hardest figure to make. If that could have any effect, however, then I should think that 3 and 5 would be next on the list but the table shows these figures to be favored rather than neglected. Series III, transits recorded by the chronograph, lends additional evidence to the belief that I have some dislike for the figure 8, for the table seems to indicate that in reading the chronograph sheets, the figure 9 has been favored at the expense of the figure 8.

With all the peculiarities of these series, I find the observations are not bad, for the computed probable error of a single transit in Series I is ± $0^s.055$ and in Series III is ± $0^s.035$ while, according to the formula of Albrecht, the probable errors should be ± $0^s.071$ and ± $0^s.052$ respectively.

MADISON, Wis., April 1, 1892.

THE EARTHQUAKE FOR FEBRUARY 23, 1892.*

WILLIAM H. PICKERING.

By a copy of the New York *Weekly Times* just received, I see that a severe earthquake shock was felt in San Diego, California, on Februrary 23, at $11^h\ 14^m$ P. M. This reduced to Greenwich mean time is $23d\ 19^h\ 14^m$. By referring to our records I find that four earthquakes are mentioned as having occurred here during the month of February, none of them being very severe. Their dates are February 4, 9, 11 and 23. The latter occured at $23d$, 21^h, 52^m, G. M. T., and is recorded as coming from the north. This is $2^h\ 38^m$ later than the one which occurred in San Diego. The approximate distance from San Diego to Arequipa, measured along a great circle, is 4,520 miles. Assuming our shock to have been identical in origin with the California disturbance, and the latter to have originated in the immediate vicinity of San Diego, this would give a mean rate of transmission of 2,510 feet per second. The distance traversed in this case is perhaps the greatest that has ever been accurately timed.

The great earthquake of 1868 shook the west coast of the whole continent, from California to Tierra del Fuego; but if accurate observations were made at that time I do not know of their ever having been collected. The great earthquakes of Lisbon and Charleston were each accurately observed through a distance of 1,200 miles. Observations made upon the Japanese and Indian earthquakes have been over still smaller distances. The velocities with which these earthquakes were transmitted when passing through the ground, have been found to vary greatly, ranging from a few hundred to over ten thousand feet per second. When the shock transmitted through the ocean on the other hand the results are much more accordant, and usually do not differ greatly from three thousand feet per second. Valuable results in the present instance might be obtained by securing observations made at other points in the disturbed area. These would give not only the mean velocities at different distances from the centrum, but would enable us to determine with some precision its approximate location.

It is proposed if possible to collect at this Observatory general data pertaining to seismic disturbances from various points along the Pacific coast. Should this plan prove practicable, it is thought that in the course of a few years many disturbances might be found which had propagated themselves to considerable distances, and from which it would be possible to locate some of the more prominent earthquake centers near this coast.

AREQUIPA, Peru, April 5, 1892.

* Communicated by the author.

THE GERMAN VARIATION OF LATITUDE WORK.*

HAROLD JACOBY.†

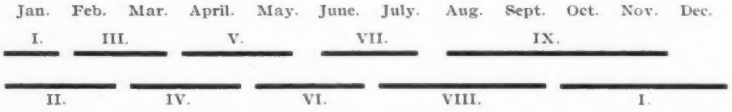
In December, 1890, Professor Albrecht published the results of the variation of latitude observations made at Berlin, Potsdam and Prague. The volume is not printed, but is merely a lithographic reproduction, and is entitled *Provisorische Resultate der Beobachtungsreihen in Berlin, Potsdam und Prag, betreffend die Veranderlichkeit der Polhohe. Auf Wunsch der permanenten Comission zusammengestellt von Th. Albrecht.* In the present article it is intended to give an account of the methods of observation and reduction described in the above work, so that they may be accessible to the readers of this Journal. The high importance of keeping a close watch upon the movements of the terrestrial pole, and the comparatively inexpensive nature of the necessary instrument, make this class of observations well adapted to the smaller observatories; where, moreover, but little time can be given to observing, and still less to computation.

The observations at all three stations were made by Talcott's method. At Berlin Dr. Marcuse observed with a bent transit constructed by Bamberg, and having an aperture of 11.5 cm. It was mounted upon a pier of such height that the object-glass was almost in the open air when the telescope was pointed at the zenith. The Potsdam observations were made by Mr. Schnauder with a zenith telescope of 6.8 cm. aperture. This instrument has a straight telescope, and is modelled after the pattern of the earlier Coast Survey instruments. It has a diagonal eye-piece of considerable length, which is turned towards the east or west in observing. The micrometer is between the prism and the eye. The Prague observations were made by Professor Weinek and and Dr. Gruss with a bent transit of 6.8 cm. aperture. Each instrument was provided with *two* delicate latitude levels, both of which were read at each observation, whenever possible.

It is well known that the weak point of Talcott's method lies in the uncertainty of the declinations. But it is possible to determine the *variation* of latitude so as to be entirely independent of the declination errors. If we could observe a certain series of stars throughout an entire year, we should obtain the variation of latitude free from the uncertainty of the declinations. Of course this cannot be done, owing to the impossibility of

* Communicated by the author. † Columbia College Observatory, New York.

observing during daylight. We are therefore compelled to change one set of stars after it has been observed a certain length of time, and begin upon a new set. Now if we arrange matters so that the period of observation of the new set overlaps that of the old set by several weeks, we can derive from the overlapping observations the systematic differences between the sets. In this way we can get a value of the variation, which is independent of the declinations. Accordingly the following program was adopted at each station. Nine sets of stars were selected, each set containing eight or nine pairs, extended over about two hours of right ascension. On every clear night two sets were observed, and they were so arranged that *at least* three weeks' overlapping observations were secured for each pair of consecutive sets. The periods of observation were arranged in the following way:



The Roman numerals designate the numbers of the sets, and the lines show approximately how they overlap. In selecting pairs the following rules were adopted:

1. The mean of all the declinations of any set must not differ more than 1′ from the latitude of the station.

2. The difference in right ascension of the two stars of any pair must not be less than 3^m nor more than 15^m. The difference of zenith distances must not exceed 15′.

3. The absolute zenith distances must never exceed 25°.

4. Those stars are to be given the preference whose proper motions in declination are known, and as far as possible, the two stars of each pair must be taken of equal magnitude. No stars of the 1st or 2d magnitudes should be used.

Although the present method does not depend upon the accuracy of the declinations, yet for obvious reasons it is very desirable to use only well-determined stars. Moreover it is important that the declinations derived from the several catalogues be reduced to a uniform system by the application of the proper corrections. For this purpose the system of the *Berlin Jahrbuch* has been adopted. I have thought it desirable to set down in a table the systematic corrections which have been applied to the declinations of the other catalogues. These corrections for the older catalogues have been taken from the table given by Auwers in *Astr. Nach.* No. 1536, to which I have added the further cor-

rections given by Auwers in *Publ. der Astr. Gesellsch.*, No. XIV, p. 12. The corrections for the Greenwich seven-year, new seven-year, and nine-year catalogues, as well as Pulcowa, 1845, have been taken from Auwers' *Publ. der Astr. Gesellsch.*, XIV, p. 10, 11. The Greenwich ten-year corrections are from a table given by Romberg in his new Pulcowa catalogue.* Declinations taken from the *Jahrbuch*, from Auwers' *Bradley*, or from Safford's catalogue have been used without correction. Whenever the proper motion was known, it was allowed for in the reduction to mean and apparent place. Several declinations were specially determined in the meridian by Küstner and Becker.

With regard to the adjustment of the instruments, the observers made it a rule never to let the azimuth error exceed 1^s, while the collimation and level errors were kept under $0^s.7$. Observations to determine these errors were made at least once a month. The barometer was read every night: and the temperature was noted both within the observing room, and in the open air. The bisection of the stars with the micrometer thread was effected four or five times at each transit, in order to eliminate errors of observation. These bisections were always made at certain fixed points, marked by vertical threads, and symmetrically situated with respect to the middle thread. *Both* latitude levels were read before and after each observation, whenever possible. To avoid error the two levels were numbered differently; one running from 0 to 50, the other from 50 to 100. The bubbles were kept as near as possible to the middle points of the tubes. At two of the stations it was found necessary to discontinue temporarily the use of one of the levels, as the observations showed that the tubes were not working well. After a thorough overhauling, they were found to be again in good condition. This circumstance shows the great importance of using two levels. When discordant observations occur, they can be traced to the level, if the fault is in that part of the instrument. The appearance of the star-images, and the steadiness of the air were recorded every night.

The reduction of the observations was carried out according to a plan which we will now outline briefly. This plan is not altogether rigorous, and the final results obtained are characterized by Dr. Albrecht as *provisional* only. Yet a complete definitive discussion of the observations would certainly not produce a change of more than a few hundredths of a second in any of the final results. The observations were first reduced in the

* Many of the above references were kindly sent to me by Professor Albrecht.

usual way, by applying the customary terms for micrometer, level, and refraction to the mean of the apparent declinations of the pair. The "reduction to the meridian" was also applied, and as far as posssible, the periodic and other errors of the micrometer screws were taken into account. The Prague screw had not been investigated, however, at the time the observations were reduced. The reductions from mean to apparent place were carried out in duplicate by means of the formula:

$$\Delta\frac{\delta+\delta_1}{2}=A\frac{a^1+a^1_1}{2}+B\frac{b^1+b^1_1}{2}+C\frac{c^1+c^1_1}{2}+D\frac{d^1+d^1_1}{2}+\tau\frac{\mu^1+\mu^1_1}{2}.$$

Having obtained in this way the separate values given by each observation of the several pairs, we can proceed to the combination of the observations, so as to derive the variation of latitude free from errors of declination.

For this purpose we begin by adjusting the declinations within each of the sets of eight or nine stars, so that they will conform to what may be called the mean declination system of that particular set. This is accomplished by comparing the mean value of the latitude as derived from all the observations of any particular pair with the corresponding mean value from all the eight or nine pairs of the set. The difference is the reduction which must be applied to all observations of the pair in question, so as to bring them into uniformity with the mean declination system of the set. Of course, in carrying out this adjustment, only the observations of those nights should be used during which all the pairs of the set were observed. Obviously the mean of all these reductions for any set must be zero. It is to be noted that the Potsdam observations showed slight discordances, probably resulting from astigmatism in the observer's eye. If the pair was observed in the order *circle-west—circle-east* the resulting latitude was too great by about 0″.18. The same pair observed in the reverse instrumental order gave a result which was too small by about the same amount. Accordingly a correction was applied to all the Potsdam observations, to remove the effect of this discordance. The correction was not quite constant, six different values being used during the period of observation. An error of this kind is almost completely eliminated from the results if the pairs of any evening are observed alternately *circle east—circle west* and *circle west—circle east*. Perhaps the use of a small reversing prism attached to the eye-piece would remove the trouble altogether. For the prism could be so turned that the micrometer thread would always appear to be horizontal, and to move in a vertical direction.

Reduction of Various Catalogue Declinations to the System of the Berlin Jahrbuch.

Part I. Depending on the Declination.

Decl.	12 yr. 1840	12 yr. 1845	Radcl. 1845	Pulk. 1845	6 yr. 1850	7 yr. 1860-64	9 yr. 1872	10 yr. 1880
°	″	″	″	″	″	″	″	″
90	+ 0.59	+ 0.58	+ 1.10	+ 0.16	+ 0.47	+ 0.19	+ 0.04	
85	+ 0.66	+ 0.47	+ 1.35	+ 0.17	+ 0.37	+ 0.23	0.00	− 0.04
80	+ 0.56	+ 0.38	+ 1.50	+ 0.19	+ 0.26	+ 0.26	− 0.05	0.00
75	+ 0.39	+ 0.30	+ 1.48	+ 0.21	+ 0.14	+ 0.27	− 0.12	+ 0.05
70	+ 0.26	+ 0.26	+ 1.23	+ 0.25	+ 0.05	+ 0.27	− 0.20	+ 0.13
65	+ 0.09	+ 0.20	+ 0.90	+ 0.28	− 0.04	+ 0.22	− 0.30	+ 0.21
60	− 0.04	+ 0.08	+ 0.54	+ 0.27	− 0.17	+ 0.12	− 0.43	+ 0.24
55	− 0.14	− 0.11	+ 0.13	+ 0.22	− 0.34	+ 0.01	− 0.56	+ 0.18
50	− 0.15	− 0.30	− 0.22	+ 0.15	− 0.47	− 0.06	− 0.62	+ 0.10
45	− 0.22	− 0.49	− 0.58	+ 0.06	− 0.59	− 0.13	− 0.64	+ 0.04
40	− 0.34	− 0.54	− 0.88	− 0.03	− 0.55	− 0.16	− 0.64	0.00
35	− 0.51	− 0.43	− 1.08	− 0.08	− 0.37	− 0.17	− 0.60	− 0.02
30	− 0.53	− 0.28	− 1.10	− 0.05	− 0.14	− 0.13	− 0.53	− 0.01
25	− 0.41	− 0.18	− 0.98	− 0.02	0.00	− 0.04	− 0.55	+ 0.13
20	− 0.30	− 0.22	− 0.88	− 0.02	0.00	− 0.04	− 0.62	+ 0.30
15	− 0.12	− 0.29	− 0.78	− 0.03	− 0.07	− 0.07	− 0.74	+ 0.32
10	0.00	− 0.26	− 0.59	− 0.05	− 0.09	− 0.13	− 0.90	+ 0.31
5	+ 0.08	− 0.19	− 0.36	− 0.07	− 0.06	− 0.23	− 1.10	+ 0.25
0	+ 0.04	− 0.24	− 0.27	− 0.11	− 0.12	− 0.37	− 1.33	+ 0.18
− 5	− 0.09	− 0.46	− 0.30	− 0.16	− 0.33	− 0.58	− 1.54	+ 0.20
− 10	− 0.30	− 0.77	− 0.46	− 0.22	− 0.64	− 0.80	− 1.70	+ 0.23

Part II. Depending on the Right Ascension.

R.A.	Radcl. 1845	Pulk. 1845	9 yr. 1872	10 yr. 1880	R.A.	Radcl. 1845	Pulk. 1845	9 yr. 1872	10 yr. 1880
h	″	″	″	″	h	″	″	″	″
0.0	+ 0.12	+ 0.16	− 0.10	+ 0.13	13.0	− 0.05	− 0.06	+ 0.06	− 0.07
1.0	+ 0.05	+ 0.10	− 0.08	+ 0.12	14.0	+ 0.03	+ 0.03	+ 0.03	− 0.15
2.0	− 0.03	− 0.05	− 0.06	+ 0.07					
3.0	− 0.11	− 0.10	− 0.02	+ 0.01	15.0	+ 0.11	+ 0.09	0.00	− 0.16
4.0	− 0.18	− 0.10	+ 0.03	− 0.04	16.0	+ 0.18	+ 0.12	− 0.02	− 0.13
					17.0	+ 0.24	+ 0.12	− 0.04	− 0.03
5.0	− 0.24	− 0.06	+ 0.06	− 0.05	18.0	+ 0.28	+ 0.10	− 0.06	+ 0.05
6.0	− 0.28	− 0.02	+ 0.08	− 0.05	19.0	+ 0.30	+ 0.06	− 0.07	+ 0.08
7.0	− 0.30	0.00	+ 0.10	− 0.03					
8.0	− 0.31	− 0.03	+ 0.10	− 0.01	20.0	+ 0.31	0.00	− 0.08	+ 0.08
9.0	− 0.29	− 0.15	+ 0.11	− 0.01	21.0	+ 0.29	− 0.06	− 0.09	+ 0.06
					22.0	+ 0.25	− 0.05	− 0.10	+ 0.03
10.0	− 0.25	− 0.22	+ 0.11	+ 0.02	23.0	+ 0.19	+ 0.10	− 0.10	+ 0.08
11.0	− 0.19	− 0.22	+ 0.10	+ 0.04	24.0	+ 0.12	+ 0.16	− 0.10	+ 0.13
12.0	− 0.12	− 0.16	+ 0.08	+ 0.02					

XUM

The corrections and reductions so far described having been applied, the mean results were taken from each set of stars for every night during which the set was observed. To arrive at the variation of latitude it still remained to deduce the systematic differences between the mean declination systems of the consecutive sets. For this purpose we use the overlapping observations. Thus for set I and set II the mean results for the several nights of the overlapping period were united into two general means. The general mean for both sets therefore corresponded very nearly to the same instant of time; and the difference between the two general means, taken with the proper sign, is the *reduction* of the declination system of set II upon that of set I. Now the return of the earlier sets at the end of a year enables us to arrange a least-square adjustment of the reductions obtained from the overlapping observations. Clearly the cyclical sum of these reductions, beginning and ending with the same set, must be zero. So that if the first set is observed again at the end of the series, we have a conditional equation which must be exactly satisfied by the *adjusted* values of the reductions. If the observations have been continued more than a year, we shall get more than one such conditional equation. The observed value of the cyclical sum may differ from zero by several tenths of a second. Thus the German observations gave:

	Berlin.	Potsdam.	Prague.
	″	″	″
Set I..... I.	−0.43	−0.16	
Set II..... II.	−0.41	−0.28	−0.12
Set III.....III.	−0.24	−0.33	−0.25
Set IV..... IV.	−0.16	−0.36	−0.27
Set V..... V.			−0.42

The agreement of these values must be due to a cause other than accidental; and Dr. Küstner has pointed out that an increase of Struve's aberration constant of 0″.07, would remove the systematic nature of these discordances.

A solution of the equations for each station having been made by the method of correlates, the final adjusted values of the systematic reductions are obtained. These now satisfy exactly the condition that all the cyclical sums are zero. But it should be observed that a *rigid* discussion of the observations would require the introduction of the aberration constant as an unknown. Moreover, the cyclical condition assumes that there is no proper motion beyond that allowed for, and furthermore takes no account of certain other possible sources of discordance.

By adding the successive reductions of the consecutive declination systems, we can get the reduction of each system to one of their number, selected as standard; or if desired, to a system which would represent the mean of all. After the application of these last corrections, we may regard the means for each night as free from the uncertainty of the declinations, so far as variation of latitude is concerned. The final results so obtained showed that at Prague, where two observers took part in the work, an appreciable systematic difference existed between them. There is no very apparent explanation of this: but on the average Professor Weinek made the latitude 0″.16 larger than Dr. Gruss. A correction of ± 0″.08 was therefore applied to these observations, so as to refer them all to the mean system of the two observers. The final results, after all the corrections had been applied, exhibited at all three stations a variation of latitude of about 0″.5, as is now well known.

Before closing the present brief account of the German observations, attention should be called to a paper by Dr. Küstner* upon the determination of the constant of aberration by means of observations with the zenith telescope. Dr. Küstner points out that in order to secure the simplest conditions for obtaining both the variation of latitude and the constant of aberration, we should select only four sets, each of which may extend about two hours in right ascension, the mean right ascensions being at about 6^h, 14^h, 18^h, and 22^h. Such an arrangement would of course necessitate considerable observing after midnight. For we should have to observe each set during its entire period of visibility, beginning with observations just before sunrise and ending with observations just after sunset. But we would only have to observe during two hours each night, except during the overlapping periods, when four hours would be necessary. In the latter case, there would always be an opportunity for rest between the first two-hour watch, and the second one. If two observers are to take part in the work, as at Prague, it would perhaps be more convenient to have them observe alternate sets, instead of alternate nights. For there would then be considerable periods of complete rest for each observer. Of course any constant personal difference would still be eliminated from the cyclical sum:—in fact, the reductions of the consecutive declination systems would *include* any such personal differences. During the overlapping periods both observers would of course be on duty each night, one in the evening, the other in the early morning.

* *Astronomische Nachrichten*, No. 3105.

PHYSICAL OBSERVATIONS OF MARS.*

DR. TERBY, LOUVAIN, FRANCE.

I impatiently awaited the opposition of Mars in 1888 to try on this planet the power of my new 8-inch equatorial constructed by Sir Howard Grubb. Unhappily the small altitude of the star above the horizon and its distance did not permit me to hope for very complete results. When I shall have added that during the course of my observations, the most detestable atmospherical conditions continued to prevail, one will not be astonished to find the facts narrated here very insignificant in comparison with those which M. Schiaparelli has verified under the sky of Milan during much more favorable oppositions, with the aid of an instrument of almost the same size and an incomparably acute eye. While, under good conditions, the Grubb equatorial has already supported perfectly a power of about 650 diameters in observing Saturn and the Moon, for example, it has scarcely tolerated the power of 280 diameters during this unfavorable opposition of Mars.†

During the course of the observations, important news arrived from Nice, where M. Perrotin, aided by a telescope which is surpassed only by that at Mt. Hamilton, verified some most interesting facts; these facts can be placed in three categories: 1st, facts relative to Libya; 2d, presence in the north polar spot of a black streak as of ink; 3d, verification of the existence of the canals and of their doubling. On another side, M. Schiaparelli wished to keep me posted in the new discoveries which he made every day at Milan with his Merz 18-inch; I learned that he too saw the details noted by M. Perrotin. And at Louvain, on my side, by the aid of the 8-inch, I confirmed the existence of the black thread in the polar spot, that of a great number of canals, and the doubling at least of Phison. I also observed Libya distinctly. In proof of the actuality of these facts, I have mentioned some of my results in the *Comptes rendus*, *in Ciel et Terre*, and in Flammarion's *l'Astronomie*.

These partial and scattered notes could only give a very incomplete idea of the Louvain observations; six drawings (the total number published) printed in *l'Astronomie* have not even been ac-

* Extract from Vol. LI. of *Memoires couronnes et Memoires des savants estrangers*, published by the Royal Academy of Sciences, Letters, and Fine Arts of Belgium. Translated by Roger Sprague.

† And yet Dr. Terby speaks in his notes of having used 650 on Mars. Evidently, his meaning here is not clear.—*Translator.*

companied by a note as to the days and hours; further, these drawings do not represent the planet as it was really seen, but (to reduce their number) I have often collected the details furnished by many evenings' observation; whatever may be their importance in verifying the maps of M. Schiaparelli, they could not serve to give a perfect idea of the results obtained. A complete work alone, comprising all the details of observations made at Louvain, could fill these deplorable gaps, and that is the object of the present memoir.

Our principal end was the verification of the admirable maps of M. Schiaparelli, maps which are yet, even to-day, it is necessary to confess with regret, the object of an entirely unjustifiable suspicion. We took inspiration from the principle announced by some great observers: "Often," they say, "one can see well what one especially seeks;" M. Otto Struve would probably never have discovered the Maia nebula with the aid of the great Pulkowa equatorial if he had not been forewarned of its presence by the photographs of the MM. Henry, and if he had not sought it with attention. Likewise, we have sought the canals of Mars in the regions where we knew that M. Schiaparelli had proved them to exist; we have taken care to calculate in advance the approximate longitude of the central meridian for each observation, and, map in hand, we have patiently and obstinately pursued these very difficult details. It is to this method, we do not hesitate to say, we owe our partial success.* As M. Perrotin himself says, all this does not leap to the eyes even in the largest telescope; for succeeding here, the greatest attention and perseverance are necessary. With still more reason, the observer armed with a simple 8-inch in the unfavorable circumstances which we have experienced, would be discouraged very quickly if he was not sustained in advance with an unbreakable faith in the truth of the Milan results; this faith alone, in effect, could inspire him with the perseverance and, I may say, the obstinacy necessary. Furthermore, prodigious difficulties are a great help to incredulity, and it is permissible to believe that observers provided with adequate means, who have not succeeded in seeing the can-

* The translator can not entirely agree with this principle. The first time I ever looked at the Andromeda nebula, the definition was perfect, and I saw the "granular texture" of the principal condensation distinctly. Yet I knew nothing of it in advance, and my telescope was only a 6-inch. Such excellent observers as Swift and Barnard tell me that, with very much larger telescopes, they have specially sought for this granular appearance, and have never met with any success. On the other hand I may say that in observing the Moon with a 2-inch telescope I never saw the Hygines and Ariadæus rills until I identified their places by means of a map. Yet Neison calls them easy objects for such a telescope.

als and their doubling, have often abandoned the observation through lack of preliminary confidence or of anterior knowledge of the details sought for.

The north polar spot was constantly visible, white, brilliant, and reduced to very small dimensions; at times when the definition was best and especially with the powers 450 and 650, I saw its elliptical form perfectly and I observed that this ellipse was entirely on the interior of the visible disk, tangent to the limb.

Towards the south pole a marked whiteness always prevailed; further, one saw appear, from time to time, in these whitened regions, some shining, snowy, well-defined spots, but which in general I did not believe to belong to the south polar spot properly so-called; these are explained by the presence of special regions which shall be discussed further on, such as Hellas, Argyre, Thyle, Noachis (?), Thaumasia (?), notably.

Only the very small white and shining spot, entirely like a polar spot, observed on the 29th of April to the south of the Kaiser sea, left me in some doubt as to its nature and perhaps made parts of the south polar spot generally invisible in 1888; or might Novissima Thyle be seen there in spite of the fact that it seemed that its high southern latitude should remove it from sight?

Let us pass on to the most interesting feature offered (in 1888) by the north polar spot, a feature observed independently at Milan, at Nice, and at Louvain; I refer to a black streak dividing this snow-cap into two parts. Here are the observations which I have been able to make by the aid of the excellent Grubb instrument. Even before the 12th of May I had noticed something like a division in this polar spot; unfortunately I took the fact for an illusion due to the unsteadiness of the image and I did not take any notes concerning it. On the 12th of May, from $8^h\ 15^m$ to $9^h\ 8^m$, I saw that the north polar spot was composed of two parts separated by a black streak as of ink; the part situated on the side towards the east limb (considered geocentrically) was smaller than the other. I again followed the polar spot from $9^h\ 12^m$ to $10^h\ 28^m$ the same day, and the little satellite spot's motion of rotation around the pole was very sensible, as my drawings show. At moments the black thread took the aspect of a black point isolated in the midst of polar snows. At $9^h\ 43^m$ the center of the satellite polar spot reached the central meridian; we find in this manner an approximate longitude of 204°.3 for its center. At $10^h\ 28^m$ its eastern extremity (seen from the earth) was near the central meridian which gives it the longitude of 215°.3.

[TO BE CONTINUED.]

THE PHYSICAL NATURE OF SHOOTING STARS AND AEROLITES.*

W. F. DENNING, ENGLAND.

D. I. M. Tébar, in a paper on Shooting Stars, Bolides and Aerolites, presented to the Astronomical Society of the Pacific ("Publications," Vol. III, No. 19), advances the following theory in explanation of them:

"*Shooting Stars* are ball-lightnings which abound in the upper regions of the atmosphere and under certain conditions their number over one and the same region is so considerable as to present the appearance of a shower."

"When these lightnings are formed in the lower regions of the atmosphere or, in the case of their descending far down in the same, they originate the so-called *bolides*, and when the ball-lightning darts through a cloud or through air impregnated with substances lifted up from the surface of the soil and scattered in the atmosphere through cyclones and hurricanes or volcanic eruptions, their effect is to unite all those substances into a single mass, thus forming the *meteorolite* or *aerolite*. Ball-lightnings and rains of ball-lightnings are not of frequent occurrence in the atmospheric strata immediately above the surface of the earth; still there are instances of both kinds of phenomena."

These singular conclusions apparently carry us back to the times of our forefathers and recall the discarded theories of a past age, but Dr. Tébar's explanation can hardly be regarded as consistent with present knowledge; indeed there are several objections to it. Dr. Tébar's idea that the shooting stars are ball-lightnings high in the atmosphere, while aerolites are formed by substances united by the action of electricity in the lower part of the air, implies that a great distinction exists between these bodies, whereas no such distinction appears to have been observed. It is highly probable that shooting stars, bolides and aerolites are precisely similar in their general derivation and constitution, and the physical aspect they present is entirely consistent with the view that they are small planetary bodies undergoing combustion. There are considerable differences of size and differences also as to the materials in their composition. But the train of sparks often noticed, the expansion which occurs in the nucleus, its slackening speed due to atmospheric resistance and its final resolution into hot ashes, all prove that a meteor, whether shooting star, bolide or aerolite, is formed of a substance which is partially or wholly dissipated under the action of intense heat.

* Communicated by the author.

The telescope supplies us with similar evidence as to the character of the shooting stars which are too small to admit of naked eye observation. These have no features distinguishing them from the brighter class except such as are due to their remote distance from us.

The radiant points of meteor-showers are often visible in the same places amongst the stars for long periods, and this peculiarity is quite opposed to the theory that meteors have their origin in ball-lightning. The radiant of a shower generated within our atmosphere would not preserve the same astronomical position, but must participate in the rotation of the earth. Nor should we expect the "lightnings" to recur at the same dates in different years and always from identical points on the celestial sphere.

Many circumstances justify the commonly accepted view that meteors are planetary bodies entering our atmosphere from the outside and are not born within it by means of electricity. Luke Howard, the meteorologist, in describing a considerable shooting star seen by him on July 29, 1813, said, "the impression it left on my mind was altogether that of a solid ignited projectile," and I believe this impression contained a truth, and that it is one often received by careful observers.

BRISTOL, May 11, 1892.

PHOTOGRAPHIC AND VISUAL MAGNITUDES OF STARS. From *Nature* May 12, 1892, the following is taken:

"At the Amsterdam Academy of Sciences on April 2, Professor J. C. Kapteyn communicated the results of an investigation of the systematic differences between the photographic and visual magnitudes of stars in different regions of the sky. The comparison of the photographic diameters of stars of equal visual magnitude (according to Gould and Schönfeld's estimations) on 370 plates of the southern sky, shows that the actinic effect of stars in or near the Milky Way is much greater than that of stars in high galactic latitudes. Professor Kapteyn has examined the different causes which lead to this variation. There is, first of all, the influence of different meteorological conditions; next, systematic errors in the catalogue of visual magnitudes used for comparison; and thirdly, peculiarities in the light of the stars. The discussion leads to the conclusion that the difference of magnitude is not appreciably affected by the first of the causes. And since, taking everything into consideration, the errors of the estimated visual magnitudes could not possibly exceed 0.3 magnitudes there is no doubt that the difference of half a magnitude or more, indicated by the photographs, is due to the quality of light emitted. It is said that Professor Pickering's idea that the Milky Way ought to be considered as an aggregation of stars of the first type is only sufficient to account for a difference of about 0.1 magnitude. Thus it appears that the light of stars in or near the Milky Way, like those of group IV, is richer in violet rays than that of other stars.

Fig. 1

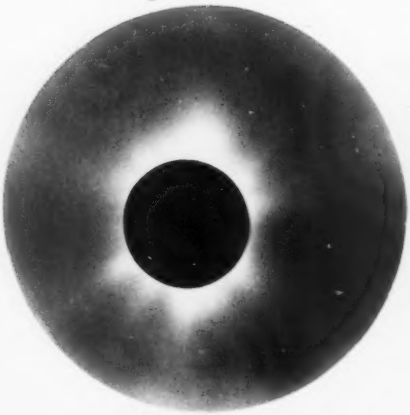


Fig. 2

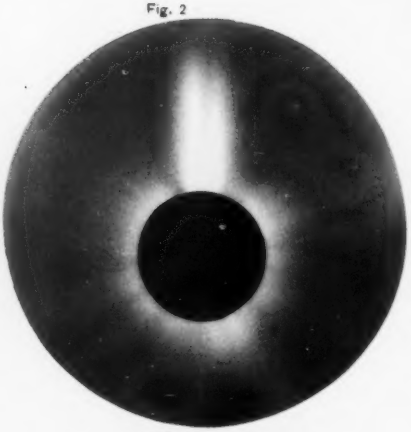


Fig. 3

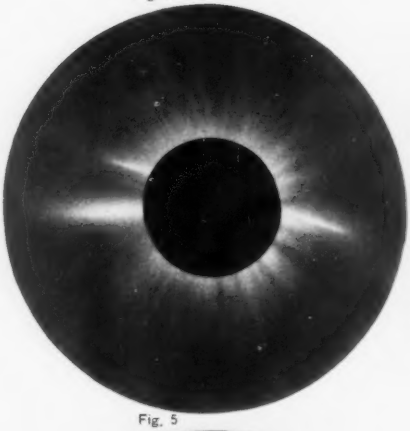


Fig. 4

Fig. 5

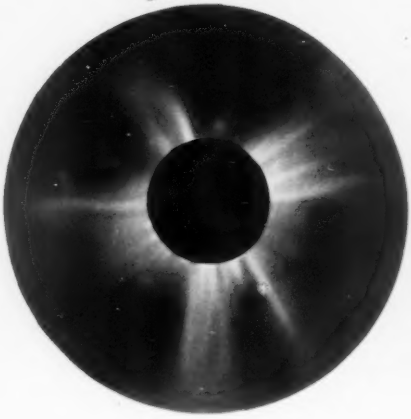
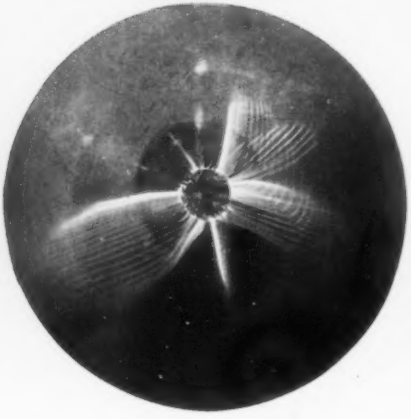


Fig. 6



CORONOIDAL ELECTRICAL DISCHARGES (PUPIN.)

XUM

ASTRO-PHYSICS.

ON ELECTRICAL DISCHARGES THROUGH POOR VACUA, AND ON CORONOIDAL DISCHARGES.*

M. I. PUPIN.

INTRODUCTION.

The behavior of electrical discharges through poor vacua does not seem to have received the attention of experimental investigators which it deserves. This may seem strange in view of the uncertainty of our knowledge of the process by which the transfer of electricity through gases takes place. Considering, however, that it was generally customary to employ in experimental investigations of this kind a vacuum jar with metal electrodes in connection with an electric generator of small capacity, it is easily explained why the discharges through poor vacua should have received so much less attention than the discharges through high vacua and the spark discharges through gases at ordinary pressures. Neither the vacuum jar nor the working of the electric generators ordinarily employed admitted of rapid, easily adjustable, but essential variations in the conditions of the experiment; as, for instance, variations of the size and shape of the electrode, of the frequency of the discharges, of the strength of the electromotive force, etc. But as I shall point out in the course of this paper, it is through these very variations that certain fundamental features in the character of an electrical discharge through poor vacua are brought out prominently.

The fact that electrical discharges in poor vacua resemble in many characteristic details the appearance and behavior of the solar corona, attaches additional interest and importance to that class of experimental investigations which are pointed out, only, in this paper. Neither time nor facilities permitted me to aim at anything approaching completeness. The principal aim in my presenting this paper was to recommend my subject and my method of investigating it to those who have command over a larger experience and skill in experimental investigations, and who also have more leisure and greater experimental facilities than I could even pretend to possess.

* Read before the National Academy of Sciences, Washington, April 22, 1892.

XUM

DESCRIPTION OF THE EXPERIMENTAL METHOD.

A brief description of the method by which I obtained my vacuum discharges seems in place now. It consists in producing an electrical current in a vacuum by means of the condenser effect of tinfoil coatings or other conductors placed on the outside of a vacuum jar.

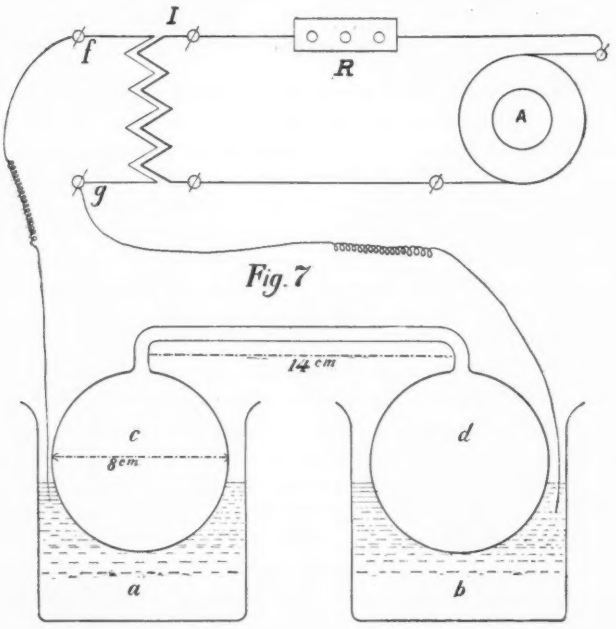


Fig. 7

The following experiment which I performed over a year ago will explain my meaning more fully. The poles, *f*, *g*, (Fig. 7) of a small Ritchie induction coil are connected to two glass beakers, *a b*, containing water. The primary is fed by ¼ HP alternator *A*, giving an alternating current of about 80 periods. A resistance box *R*, regulates the strength of the primary current. The speed of the motor which drives the alternator regulates the periodicity of the current.

A vacuum jar *c d*, consisting of two glass bulbs (each about 8 c. m. in diameter) connected by a tube of narrow bore, was immersed into the beakers, one bulb in one beaker, the other into the other. The jar contained rarified air at about 5 mm. pressure.

As soon as the bulb reached a certain depth a discharge took place, producing a perfectly steady and continuously diffused crimson luminosity. The intensity of the luminosity increased with the increase of the surface of contact between the water and the bulbs. The same effect was produced by substituting a Holtz machine for the induction coil and the alternator. In this case the effect was due, of course, to the oscillations produced by the spark discharge between the poles of the machine. The two vacuum bulbs with the water surrounding them act like two condensers connected in series by the narrow tube. It seems superfluous to describe the obvious experiments which I had to perform to prove the following relation:

The intensity of the luminosity increases with the condenser surface of the bulbs, with the frequency of alternations, and with the effective electromotive force of the charging apparatus. Other things being equal, the total amount of light produced will increase with the increase of the conductivity of the vacuum. This relation may have been understood before, but to my knowledge it was never clearly stated.

The luminous effects which I succeeded in producing in the manner described were so powerful, that I thought it worth while to construct an electrical lamp on this principle. I mention this for the purpose of pointing out that this method of producing very powerful vacuum discharges was worked out by me several months before the publication of Nikola Tesla's and Professor J. J. Thomson's magnificent experiments. A considerable number of results which I obtained in my experiments are simply repetitions, on a small scale, of the results obtained by these scientists. There is, however, one line along which there seems to be but very few points of contact between their work and mine. This line runs in the direction of investigating the relation between the character of the discharge, the pressure in the vacuum, and the effective e. m. f. which produces the discharge. The following experiments will show some of the characteristic features of this relation.

ON THE CRITICAL POINTS OF THE DISCHARGE.

A vacuum jar, of the form and dimensions as given in Fig. 8, was substituted for the small double bulb *c d* in Fig. 7. The bulbs *A* and *B* were totally immersed in large glass beakers, containing clear, distilled, acidulated water. The air pressure in the bulbs was a little less than 2 mm. Instead of a small alternator a large alternating current machine fed the primary. On closing

the primary circuit the discharge between the bulbs started long before the resistance box, *R*, indicated that the e.m.f. in the secondary coil had reached its maximum. The crimson luminosity was very soft, steady, and distributed in accordance with the distribution of the potential which one would expect in an electrical system of the above description. Touching the narrow tube at any point increased the luminosity below the point touched; evidently due to the increase of the static capacity at that point. Diminishing gradually the e.m.f. the luminosity of the discharge diminished with it, and then stopped suddenly as if a critical point had been suddenly reached. Reducing the e.m.f. gradually to zero and then gradually increasing it again, it was found that the discharge would cease at a point much lower than the point at which it would start again, the difference between the two points diminishing considerably with the rapidity with which these variations were made. The discharge will start at a much lower e.m.f. if solicited; that is to say, if the long tube is touched at one or more points. A wire bent in the shape of a Leyden jar discharger does very good service as a discharge "solicitor."

The discharge was similarly affected by varying the capacity. Performing the last experiment, but with the small vacuum jar *c d* given in Fig. 7, it was found that with a given low potential the discharge did not start until the bulbs *c d* had reached a certain depth, and then it started suddenly. Raising the bulbs gradually, and therefore diminishing the capacity, the discharge became fainter and fainter, but it did not cease until the bulbs were entirely lifted out of the water. On immersing again, the discharge did not start until a certain depth was reached. The depth at which the discharge would start this time was smaller than in the first case, and the smaller the shorter the interval between the time of taking the bulbs out and immersing them again. This difference is of course due to the improved conductivity of the gas, and this again may in a certain measure be due to the rise in temperature of the gas on account of the heating effect of the discharge; but only in a small measure, for the bulbs were under water, so that the rise in temperature must have been very small. Besides, heating the bulbs with a Bunsen burner before immersion did not diminish the depth at which the discharge would start nearly as much as a previous discharge would, no matter of how short a duration. As stated above, the discharge may be started far below the critical point by touching the connecting tube. But if the touch lasts only a very short

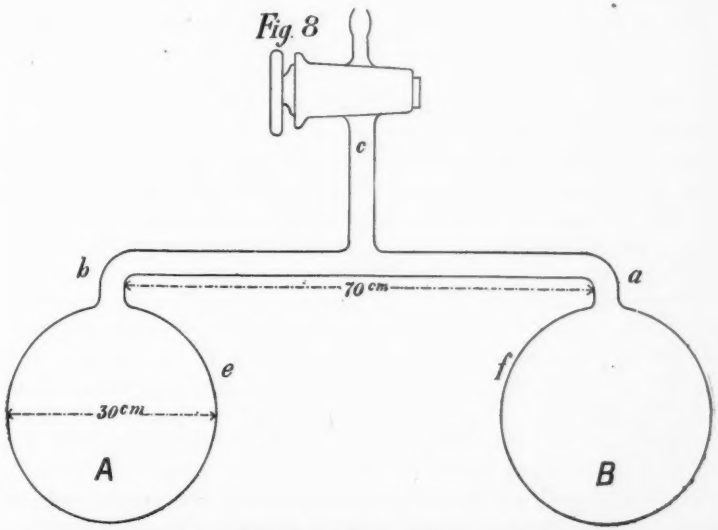
time (a fraction of a second) the discharge ceases as soon as the touching conductor leaves the tube. In this manner the vacuum tube may be made to blaze up in quick succession.

This behavior of the discharge at all pressures, but very much more striking at pressures higher than the pressure under consideration, seems to support the dissociation theory of Professor J. J. Thomson (*Phil. Mag.*, 1891, Vol. 32, pp. 329, 454, 455).

II. PHENOMENA INDICATING A DISSOCIATION OF THE MOLECULES.

The following phenomenon appears to be an additional support to this theory:

Fig. 8

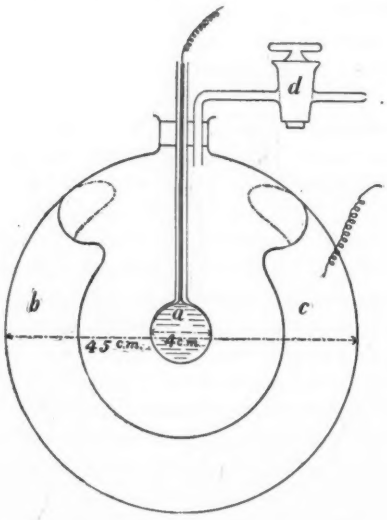


A close inspection of the discharge going on in the bulbs *A* and *B*, Fig. 8, seemed to reveal the strange fact that the electrical flow was confined to a thin layer of the rarified gas which is in immediate contact with the inside surface of the bulbs, especially when the e.m.f. was not too far above the critical point, and therefore the supply of the current not too plentiful. To all appearances there was a gliding film of luminous gas in each bulb extending from the mouths of the connecting tube, spreading over the inside surfaces, and ending at the bottom of the bulbs in violently agitated luminous clouds which gave the discharge a hazy appearance. When the vacuum was very good both the film and the clouds were absent. There was no suggestion of a

motion on the part of the gas, and the discharge had a clear luminosity. To study this phenomenon more closely the following experiment was performed:

A glass bulb, *a*, Fig. 9, blown out at one end of a thick glass tube of narrow bore, was filled with acidulated water and placed at the centre of a large glass bottle, as indicated in the figure.

Fig. 9



A wide strip (*c b*) of tinfoil was placed on the outside of the bottle, covering about one-third of the surface. The air was exhausted through the tube *d*, until the pressure was about 3 mm. The liquid in the bulb *a* and the tinfoil were connected to the secondary poles of the induction coil. When the e.m.f. was not too far above the critical point the discharge was in form of *numerous, quivering streamers*, which looked like the generators of a conical surface, with the centre of bulb *a* as vertex and the edge of the tinfoil as directing curve. There was *no visible discharge between the bulb and the central parts of the tinfoil.* But the discharge spread out and gradually approached these parts, and at the same time the streamers became less numerous and steadier, giving the discharge a more diffused appearance as the potential gradually increased. When the e.m.f. was grad-

ually brought back to its original value the discharge diminished in intensity but did not return to its original form of distribution. It did that when the e.m.f. was considerably lowered below its initial value, which showed that the original distribution was not altogether due to the fact that at any moment the density of the electrostatic charge of the tinfoils was considerably larger near the edges. In this experiment, as well as in the preceding one, the number of streamers, their definition, their quivering motion, and their preference for the paths along which the discharge started increased with the increase of pressure in the vacuum. A discharge (especially in vacua of poor conductivity) will always start between parts of highest electrical density, and each successive discharge prefers the passage along the path of the first discharge on account of the increased conductivity along this path.

But if this increase in the conductivity is due to a rise in the temperature of the gas along the path of the first discharge and to nothing else, how can the fact be explained that a long, thin, discharge streamer, when forced through a poor vacuum, can be maintained steady, and permanent in form, even if the discharge continues for several minutes? It should broaden out continually, and become more and more diffused as the adjacent particles of the air get heated. In my experiments on solitary discharge streamers in poor vacua (see *Amer. Jour. of Science*, April, 1892), I did not observe any appreciable widening out, but I did observe a phosphorescent halo around the streamer which, as Professor J. J. Thompson assumes (*l. c.*) was *very probably* due to dissociated oxygen molecules that were ejected from the path of the discharge. (See farther below the effect of a blast on a discharge streamer).

Still another experiment which shows that something of the nature of a dissociation of the gas molecules is going on along the path of the discharge. A thick German silver wire, 60 cm. long, was bent zig-zag fashion into 12 zig-zag parts, and placed in horizontal position at the bottom of a bottle like the one in Fig. 9. A wire passing through a rubber stopper in the neck of the bottle connected this zig-zag electrode to one of the poles of the induction coil. The other electrode, a small brass sphere, was vertically above the zig-zag electrode, immediately under the rubber stopper. The shortest distance between the two was about 30 cm. The vacuum was about 3 mm. The discharge started between the nearest points of the electrodes, that is, between the lowest point of the sphere and one extremity of the zig-zag elec-

trode. It had the form of a band about 3 cm. wide, intensely luminous at each end, but only very faintly luminous along the intervening three-fourths of its length. The length of the less luminous interval increased with the decrease of the e.m.f., but diminished with the increase of the gas pressure; it also seemed to have a different color, but I did not care to examine this point more closely. The phenomenon that interested me more was the gradual creeping of the discharge along the zig-zag electrode from one of its extremities towards the other. It did not increase in breadth but left its trail along the zig-zag electrode in form of a faintly luminous halo which surrounded this electrode just like a narrow luminous tube. Both the color and the gradual lateral motion of the discharge reminded me very much of the aurora borealis of Feb. 13, 1892. (In this connection it is well to remark that when the e.m.f. is below the critical point this auroral discharge can be started by powerful disruptive discharges of a Leyden jar in its vicinity. This, in connection with observations on coronoidal discharges given in the later part of this paper, may perhaps furnish a clue in tracing the connection between Sun-spots and auroral discharges.)

III. PHENOMENA INDICATING A TRANSLATIONAL MOTION OF THE GAS.

An interesting phenomenon was observed in the experiments with bulbs *A*, *B*, Fig. 8, when the vacuum was diminished by turning quickly the stop-cock *C* several times around. The vacuum pressure was about 20 mm. The induction coil had to be strained considerably to force a discharge through the long glass tube. The discharge looked like a luminous jet shooting from the tube into the bulbs, and in its path around the corners it seemed to strike against the necks of the bulbs at *a* and *b*, from which points it was reflected and glided along the surface towards the points *e* and *f*. Inside of the bulbs the jet oscillated rapidly; it was also split up in several parts, each part consisting of numerous more or less intense streamers. A slight modification in the curvature of the necks modified the general outline of the luminous jet without changing its general character. With the increase of the gas pressure the phosphorescence appeared and seemed to be strongest at *a* and *b*. It was very strong in the tube *C* leading to the stop-cock, although this tube was entirely free from the discharge proper. The height to which the phosphorescence rose in this tube increased with the current. Every slight variation in the current strength caused a simultaneous variation in the height of the phosphorescent col-

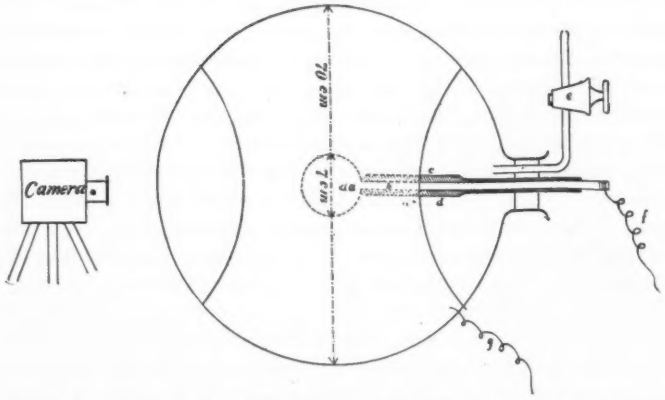
umn in *C*. (When the discharge ceased there was a strong phosphorescent after-glow all along the long tube). A similar behavior on the part of the phosphorescent gas which I observed in the experiment described in *Amer. Jour. of Science*, April, 1892, leads to the conclusion that the phosphorescent gas must have a translational motion, due to its being ejected from the path of the discharge proper. This strengthened my belief in a translational motion of the gas along the path of the discharge proper, which belief was due to the phenomena in the experiment just described. It was also strengthened by the phenomenon observed in the experiment described by me in the paper cited above, the phenomenon namely, that a discharge streamer made to curve way out (by the repulsive action of another parallel streamer), so as to strike against the walls of the vacuum jar will rebound from this wall just as a curved jet of water would if it struck against a rigid surface. In another experiment with an apparatus like the one described in the above paper, a thin rectangular sheet of mica was suspended between and parallel to two discharge streamers, and it was found that it prevented their action which I described in that paper, but it was made to swing back and forth as if acted upon by a wind coming from the path of the discharges. This action was hardly perceptible in high vacua, but increased quite considerably with the increase of gas pressure. It may, however, be due to a great variety of causes, like peculiar distribution of pressures due to a peculiar distribution temperature; so-called apparent (in my case continually varying) electrostatic charge over the surface of the mica, etc.

IV. ON CORONOIDAL DISCHARGES.

Wishing to perform additional experiments which could throw some more light on this particular feature of discharge I constructed the apparatus given in Fig. 10. A large glass bulb was coated with tinfoil along those parts of its external surface which would approximately correspond to its temperate zones, its neck being one of the poles. This tinfoil coating had a wire, *g*, attached to it by means of which it could be connected to the pole of the induction coil, and serve as an electrode of the bulb. The other electrode was a brass sphere *a* attached to a brass rod *b*. This brass rod was surrounded by a glass tube, *cd*, and the space between the two was filled with sealing wax. In this arrangement the pressure could be varied between very wide limits (up to about 100 mm.), without running the risk of refusal on the

part of the induction coil to force a discharge through. A camera was placed in front of the bulb. as indicated in Fig. 10, and the discharges photographed. Figs. 1, 2, 3, 4, 5, 6,* are photographs of the discharges obtained in this manner, but in various degrees of rarification.

Fig. 10



I shall discuss the discharge given in Fig. 6 first. In this case the vacuum was very poor (about 60 mm. pressure). The discharge started in the form of four large streamers, together with a very large number of short luminous jets which were more or less uniformly distributed over the sphere. In consequence of these jets the appearance of the sphere reminded one very much of the granular structure of the Sun's disc as revealed by Rutherfurd's, Janssen's, and Vogel's photographs of the Sun. Very luminous spots appeared from time to time at several points of the surface, which reminded one very much of the Sun's faculæ. Both the jets and the large streamers rotated rapidly. This rotation is indicated very plainly in the photograph; for the number of streamers in each wing represents the number of maxima in the alternating discharge during the time of the exposure, which was a small fraction of a second. The thickest streamers indicate the place where the discharge started. It is evident that the streamers were distributed nearly systematically over the sphere at the start of the discharge; and that then one-half of them were gradually and almost uniformly displaced

* See plate at beginning of this article.

in the direction of the motion of the hands of a watch, the other half in the opposite direction. The peculiar curvature of some of these streamers indicates the presence of two kinds of motion,—one a translational along the prolongation of the radii of the small sphere, and the other a rotational. It was this rotational motion which led me to assume that there must be some sort of repulsive action between the streamers of a vacuum discharge. The existence of this action was demonstrated conclusively by the experiment described in the paper cited above. Additional researches in this direction lead me to the conclusion that two discharge streamers tend to blow each other out owing to the motion of the cooler gas between them, this motion being produced by the enormous heating effect of the discharge. The result is that the particles of the gas which at any moment form the path of a discharge are continually displaced (particularly in a discharge through a poor vacuum), and since every successive discharge prefers the particles through which the preceding discharge passed (for reasons given above), it follows that a sort of rotary motion is set up in the various parts of the discharge.

An additional evidence in favor of a translational motion along the paths of the streamers is furnished by the fact that all along the inside surface of the large glass bulb, which is below the tinfoil coating, there is a hazy luminosity which increases with the increase of the discharge, and which to all appearances is due to an accumulation of incandescent gas molecules which had impinged against and were reflected by the surface of the bulb.

If the inside end of the exhaust tube *e*, Fig. 10, is lowered, so that it reaches the region of the discharge, it is observed that from time to time the incandescent gas shoots through this tube toward the stopcock way out of the bulb.

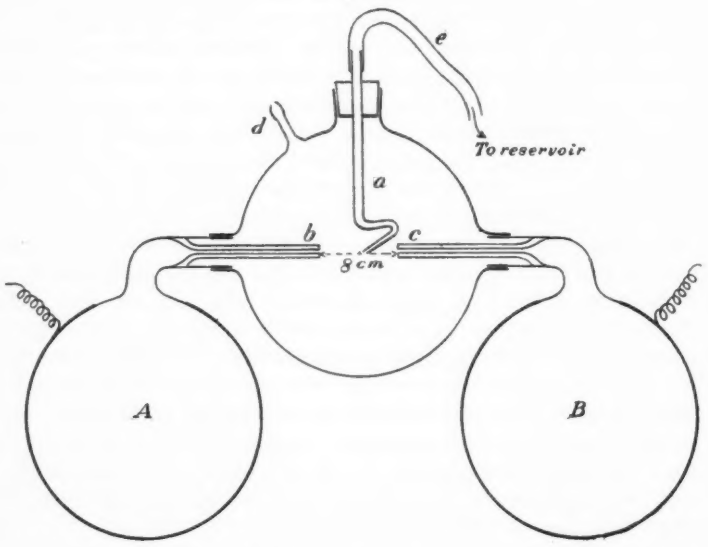
Effect of a Blast on a Discharge Streamer. Granting that there is a translational motion along the path of the streamer it follows that a rectilinear streamer may be transformed into a curved one by imparting to the gas in each part of its path a component velocity perpendicular to its original velocity. This inference was confirmed by the following experiment:

Two bulbs *A*, *B*, (Fig. 11) coated with tinfoil on the outside (the electrodes of the system) communicated with a reservoir (which I call the *principal reservoir*) by means of glass tubes *b*, *c*, of narrow bore. An L shaped tube *a* with a small orifice was fitted by means of a rubber stopper into the neck of the reservoir. By means of this tube and the tube *d* the *principal reservoir* com-

municated with two other reservoirs, which I call the *external reservoirs*.

The *external reservoir* connected with *d* communicated with a mercury pump. When the exhaustion had reached the point at which a steady rectilinear discharge could be forced from *b* to *c*, a stopcock connecting *d* to its external reservoir was shut off and the exhaustion continued until a good vacuum was obtained in the external reservoir *d*. The discharge was then started. It was a perfectly steady, narrow, rectilinear column of crimson luminosity, surrounded by a phosphorescent ellipsoidal column.

Fig. 11



But as soon as the above mentioned stopcock was turned on, the blast coming from the orifice *a* played up the column and the rectilinear path became curved at the point where the blast was acting. The discharge acted as if it bent around to get out of the way of the blast. The observation that the effect of the blast upon the phosphorescent column was imcomparably stronger than upon the crimson column needs no comment. The weaker the discharge the stronger is the effect of the blast, and *vice versa*. The effect of a blast upon the oscillatory spark discharge of a powerful Leyden jar battery is not perceptible.

In discharges through very poor vacua the heating effect is

very unequally distributed throughout the vacuum jar. The temperature at certain points is enormously higher than at others. The result is that a very violent motion of the gas is set up, which motion may sometimes, on account of the effects pointed out in the last experiment, produce streamers of double curvature.

During an experiment with the apparatus given in Fig. 10, which I performed on Feb. 8, 1892, before the astronomical section of the New York Academy of Sciences, a leak occurred, so that the vacuum was exceedingly poor by the time I was ready to start the discharge. Finding that the discharge gave no sign of starting, I risked to turn the whole power of the 10 H. P. alternator on the induction coil. Long sparks shot immediately from almost every point of the edge of the tinfoil. The discharge between the brass sphere and the tinfoil looked like a black-faced Medusa with fiery serpents dancing all around her head. On repeating this experiment, I found that in very poor vacua the discharge streamers very often assume the form of spirals of very long pitch.

All these phenomena suggested to my mind a very strong similarity between the streamers of an electrical discharge through poor vacua and those of the solar corona, and for the purpose of pointing out this similarity to others otherwise than by verbal description only, I resolved to photograph these discharges under conditions similar to those under which the solar corona is observed. Photographs 1, 2, 3, 4, 5, 6 are the result.

The discharges were obtained with the apparatus given in Fig. 10. The only additions were that a circular tinfoil disc was pasted on the outside of the large bulb, in the line of sight between the camera and the brass sphere *A*. The diameter of this disc was about equal to that of the brass sphere. Also, the inside surface of the large bulb which formed the background of the brass sphere was blackened by means of camphor smoke, to avoid reflections. The discharge in Fig. 1 is that of a good vacuum (about 2 mm.); the succeeding ones represent discharges in poorer vacua, the pressures varying between 2 mm. and 60 mm.

The bearing which these experimental results may have upon the theory of the Solar Corona, I prefer to leave to others to decide. That they may prove a suggestive guide in the study of solar phenomena seems not unreasonable to expect.

I am greatly indebted to Professor John K. Rees for the interest which he took in my work, and to Mr. Mann, of the Columbia

College Observatory, for the very valuable service which he rendered to me in photographing the coronoidal discharges.

DEPARTMENT OF ELECTRICAL ENGINEERING,
Columbia College, March 31, 1892.

ON THE LINE SPECTRA OF THE ELEMENTS.*

C. RUNGE.

The distribution of the lines in the spectra of the elements is by no means so irregular as it might seem at first sight. Since Lecoq de Boisbaudran, in 1869, discovered the general plan in the spectra of the alkali metals, a number of interesting facts have been brought to light, which will probably one of these days find their mechanical explanation, and will then greatly advance our knowledge of the molecules.

Mechanical explanations of some of the facts have been attempted already. Lecoq de Boisbaudran explains the fact that the rays of the alkali metals are, on the whole, less refrangible the greater the atomic weight, by observing that the oscillations of a body suspended in a given elastic medium will become less frequent when the mass of the body is increased. This explanation, however, seems to me to remain rather vague and unsatisfactory as long as it does not lead to any numerical results that agree with the observations. Taken literally, it makes the oscillation-frequency inversely proportional to the square root of the atomic weight, which is far from being the case.

A second well-established fact has received different explanations by Julius† and by Johnstone Stoney.‡ It has long been observed by Hartley that in the spectrum of several elements a number of doublets or triplets of lines appear, the oscillation-frequencies in each doublet or triplet differing by the same amount. Recent measurements by Professor Kayser and myself have confirmed this observation. Julius believes that this phenomenon is due to a cause analogous to the combination tones in the theory of sound.

If two rays, with oscillation-frequencies α, β, combine with other rays, p, q, r, s, to oscillation-frequencies

$$\begin{array}{cccc} p+\alpha & q+\alpha & r+\alpha & s+\alpha \\ p+\beta & q+\beta & r+\beta & s+\beta, \end{array}$$

* *Nature*, April 28, 1892.
† Julius, *Annales de l'Ecole Polytechnique de Delft*, tome v. (1889).
‡ Stoney, Trans. of the Roy. Dublin Soc., vol. iv. (1891).

the same difference $\alpha - \beta$ will occur several times. That the doublets under consideration are in many cases remarkably strong is accounted for by the fact that the intensity of the combination tone is proportional to the product of the intensities of the primary tones, so that it must become very strong when the amplitude of the primary tones is sufficiently increased.

Johnstone Stoney gives a different explanation of the doublets. He supposes that the path of the molecule from which light emanates is an ellipse, which by disturbing forces is gradually changed, and he shows that on this supposition, instead of one ray, two rays or more would originate, and the oscillation-frequencies of these rays would differ by an amount depending on the rate of change of the ellipse. If now, instead of the ellipse, the path of the molecule is any other curve, it can be considered as consisting of a number of superposed ellipses, all of which change in the same way on account of the disturbing forces. To each of the ellipses a doublet of lines corresponds, and the oscillation-frequencies of each doublet differ by the same amount. In this explanation I do not understand the decomposition of the arbitrary curve in a series of superposed ellipses. For the movement is supposed not to be periodical, and Fourier's theorem then would not apply, at least the periods of the superposed ellipses would not be definite, as long as there are no data except the arbitrary curve itself.

Besides, both Johnstone Stoney and Julius only try to explain one of a number of regularities that have been observed in the spectra of the elements. A plausible suggestion about the movement of the molecules ought to explain more than one of the observed phenomena. I think it may be useful to point out the other regularities that have been observed in the distribution of lines, and for which as yet no mechanical explanation has been attempted.

(1) The doublets and triplets existing in the spectrum of an element can be arranged in series which show an appearance of great regularity. These series seem to be analogous to the overtones of a vibrating body. But they possess a remarkable peculiarity, which, as far as I know, is without analogy in the theory of sound. The difference of two consecutive oscillation-frequencies decreases as these increase, and there seems to exist a finite limit to the oscillation-frequencies of a series. If n represents integer numbers, the oscillation-frequencies of a series may with great accuracy be represented by the formula—

$$A - Bn^{-2} - Cn^{-4},$$

where A, B, C are positive constants. B has nearly the same value for all the series of the different spectra. A is the limit towards which the oscillation-frequency tends, when n increases.

(2) For elements that are chemically related, the series are distinctly homologous, both in appearance of the lines and in the values of A, B, C, and with increasing atomic weight shift towards the less refrangible end of the spectrum. Homologous series have been observed in the following groups of elements:—

Lithium, sodium, potassium, rubidium, cæsium;
Copper, silver;
Magnesium, calcium, strontium;
Zinc, cadmium, mercury;
Aluminium, indium, thallium.

In the first two and in the last group the series consist of doublets,* while in the remaining two groups they consist of triplets. Thus we may say that the spectrum shows a relationship between the elements similar to that between their chemical properties. It is interesting to note that magnesium forms a group with calcium and strontium, and appears more nearly related to them than to zinc, cadium, and mercury.

(3) The doublets and triplets in each group broaden as the atomic weight increases. In the first group the difference of oscillation-frequencies is nearly proportional to the square of the atomic weight. The constant difference of the oscillation-frequencies in the doublets and triplets may also be noted in the values of A, B, C. For a series of doublets or triplets we have two or three different values of A, but only one value of B and one value of C.

(4) In each of the spectra of sodium, potassium, rubidium, and cæsium, a series of doublets has been observed, in which the oscillation-frequencies do not differ by a constant amount, the difference diminishing inversely proportional to n^4. For these series A and B have only one value each. The least refrangible doublet of the series has the same difference of oscillation-frequencies as the doublets in the other series of the same element. In the spectrum of lithium there is a homologous series of single lines. All the lines of these series have the same character; they are strong and easily reversed, and in all of them the first doublet is situated on the less refrangible side of the spectrum, and all the others in the violet and ultra-violet. The series shift towards the less refrangible side with increasing atomic weight.

For further details the reader is referred to the following

* Lithium has here to be excepted, whose lines are all single.

memoirs:—Kayser and Runge, "Ueber die Spectren der Elemente," *Abhandl. der Berl. Akademie*, 1890-92; Rydberg, "Recherches sur la constitution des spectres d'émission des éléments chimiques," *Kongl. Svenska Vetenskaps-Akademiens Handlingar*, Bandet 23, No. 11, 1890.

HANNOVER, Germany.

ON THE LARGE SUN-SPOT OF 1892, FEBRUARY 5-18, AND THE ASSOCIATED MAGNETIC DISTURBANCE.*

As the large spot seen on the Sun 1892, February 5–18, was the largest which has been photographed at Greenwich, and as its presence appears to have been associated with a great magnetic disturbance, some particulars may be of interest, though they must necessarily be imperfect pending the arrival of photographs from India and Mauritius to supplement the Greenwich series.

At Greenwich photographs of the Sun were obtained on five days during the first appearance of the group, viz. on February 5, 13, 16, 17 and 18; and up to the present time on three days during its second appearance, viz. on March 5, 7 and 8. The following table gives the heliographic coördinates of the center of the great spot, and the total area of the entire group, expressed in millionths of the Sun's visible hemisphere, for each day of observation during its first appearance:

Date G. Civil T.			Distance from Centre in terms of Sun's Radius.	Position-Angle from Sun's Axis.	Heliographic			Area.	
					Longitude from Central Meridian.	Longitude from Prime Meridian.	Latitude.	Umbra.	Whole Spot.
	h	m		°	°	°	°		
Feb. 5	10	24	0.985	118.4	− 81.9	259.0	− 29.0	96	1522
13	9	47	0.488	217.5	+ 19.8	255.6	− 29.2	451	2999
16	9	40	0.859	248.4	+ 58.5	254.9	− 28.1	256	2288
17	12	10	0.938	241.3	+ 70.4	252.3	− 29.3	139	1433
18	11	58	0.986	240.6	+ 82.5	251.3	− 30.1	84	1389

The great spot was on the central meridian February 11, 22^h G. C. T. On February 13, when the group was best seen, being then nearer the center of the disc than on any of the other days of observation, the group extended in heliographic longitude from 270° to 245°, a length of 25°; and in heliographic latitude from 23° S. to 33° S., a breadth of 10°. The principal spot of the group had a length of 14°, from 263° to 249°, and a breadth of 8°, from 25° S. to 33° S.

* *Monthly Notices*, March 1892. Communicated by the Astronomer Royal.

The group had greatly diminished in area when it reappeared on the east limb on March 5.

The following table gives the position of the principal spot and area of the entire group, as observed up to the present time, during its second appearance:—

Date. G. Civil T.			Distance from Centre in terms of Sun's Radius.	Position-Angle from Sun's Axis.	Heliographic			Area.	
					Longitude from Central Meridian.	Longitude from Prime Meridian.	Latitude.	Umbra.	Whole Spot.
	h	m		°	°	°	°		
Mar. 5	9	51	0.927	118.3	− 68.4	250.9	− 28.8	28	208
7	9	54	0.714	124.0	− 42.4	250.4	− 28.9	34	510
8	10	39	0.571	132.8	− 28.5	250.8	− 29.2	35	521

It will be seen that the group has greatly diminished in area during the fortnight in which it was on the further side of the Sun. There seems, however, a slight tendency to increase again, especially with regard to the principal spot, the area of which rose from 101 on March 5 to 369 and 448 on March 7 and 8. The great spot has undergone but little change of place during the interval, for its latitude has remained practically unchanged, and though its longitude, as computed with a sidereal period of 25.38 days, appears to show a slight diminution, this is due to the rotation period of the Sun being longer for high latitudes, the rotation period adopted corresponding to a latitude of about 15°.

A great magnetic disturbance accompanied by an aurora, occurred on 1892, February 13–14, commencing about a day after the large spot was on the central meridian of the Sun's disc. The following particulars have been drawn up by Mr. Ellis:—

The magnetic disturbance commenced in all elements on February 13 at $5^h\ 32^m$, Greenwich Civil Time, by a sudden increase of declination, horizontal force, and vertical force, accompanied by strong manifestation of earth currents. Large motions were registered in all elements; between February 13, 19^h, and February 14, 3^h, they were unusually large, amounting to more than 1° in declination, the trace having passed off the sheet for one hour shortly after midnight. In horizontal force the disturbance exceeded 0.029 of the whole horizontal force, the trace having similarly passed off the sheet for nearly half an hour at about 22^h, and afterwards for more than 1½ hours from shortly before 1^h to $2\frac{1}{2}^h$. In vertical force the disturbance was also great, the trace having gone off the sheet in the direction of increasing force from $14\frac{1}{2}^h$ to 19^h, and in the direction of decreasing force from $0\frac{1}{2}^h$ to 2^h; the motion probably exceeded 0.020 of the whole vertical force. The disturbance ceased on the evening of February 14.

An aurora was seen at Greenwich between 0^h and 1^h, by Mr. McClellan.

The disturbance compares in magnitude with those of 1882 April and November, the registered motions being large in all elements on all three occasions. The disturbance of 1882, November, was, however, extreme, the motions then registered being apparently in excess even of those of 1882 April and 1892 February.

The following table shows how the recent disturbance compares with previous ones recorded since the commencement of the Greenwich series of solar photographs in 1873.

Particulars of Magnetic Disturbances from the Photographic Registers at the Royal Observatory, Greenwich.

Period of Disturbance. Greenwich Civil Time.							Character of Disturbance.	Extreme amplitude of Motion during Disturbance.		
			h			h		Declination.	Horizontal Force.	Vertical Force.
								° ′		
1880	Aug.	12	12	to Aug.	14	8	*c*	1 5	.016	0.08
1881	Jan.	31	12	" Feb.	1	3	*c*	1 15	.018	.008
	Sept.	12	12	" Sept.	14	2	*c*	1 0	.017	.008
1882	Apr.	16	23	" Apr.	17	23	*g*	1 0 +	.030 +	.022 +
	Apr.	20	3	" Apr.	21	8	*g*	1 10 +	.020 +	.008
	Oct.	2	10	" Oct.	3	3	*c*	1 0	.014	no register
	Nov.	17	10	" Nov.	21	4	*g*	1 50	.050 +	.025
	Nov.	21	15	" Nov.	22	0	*m*	0 40	.010	.003
1883	Sept.	16	3	" Sept.	17	17	*c*	0 50	.019	.005 +
1884	July	2	19	" July	4	6	*c*	0 40	.018	.007
	Oct.	1	22	" Oct.	3	6	*m*	0 30	.010	.004
	Nov.	2	13	" Nov.	3	8	*m*	0 45	.012	.005
1885	Mar.	15	10	" Mar.	16	6	*c*	0 55	.010	.009
1886	Mar.	30	8	" Apr.	1	3	*c*	1 5	.020 +	.007
1892	Feb.	13	5	" Feb.	14	18	*g*	1 10 +	.029 +	.015 +

In the column "Character of Disturbance" *m* indicates moderate; *c*, considerable; and *g* great.

The amplitudes in the case of Horizontal Force and Vertical Force are given in parts of these forces respectively.

The sign + attached to a measure indicates that the spot of light passed beyond the limit of registration.

Most of these magnetic disturbances occurred when an exceptionally large spot was visible on the Sun near the center of the disc, or about the time of some great change in a Sun-spot.

ROYAL OBSERVATORY, Greenwich, 1892, March 11.

ADDENDUM.

Since this note was drawn up, Mr. Maunder has found, from an examination of the photographs at Greenwich, that this Sun-spot appeared on the Sun on 1891 November 15, when it came into view close to the east limb as a spot of considerable size. It

was also photographed at its appearances in December 1891 and January 1892, so that it has persisted through five rotations, with, however, a remarkable progressive drift in latitude from about 17° S. to 30° S. Several magnetic disturbances have occurred during its presence on the Sun, three being subsequent to that on February 13, described above, viz.: March $1^d\ 0^h$ to 16^h (moderate), 0° 45′ in declination; March $6^d\ 9^h$ to $7^d\ 9^h$ (considerable), 0° 50′ in declination; March $11^d\ 10^h$ to $13^d\ 5^h$ (great), 1° 15′ in declination.

ROYAL OBSERVATORY, Greenwich, 1892, March 25.

ON A REMARKABLE PROMINENCE.*

H. DESLANDRES.

On March 3 I observed a prominence remarkable for its brilliancy and radial velocity, which, moreover, belonged to the region of the Sun occupied by the great spot of last month (February). By the rotation of the Sun this region had arrived at the eastern limb on the day in question.

At $10^h\ 12^m$ A. M., I was struck while examining the chromosphere by the unusual brilliancy of the hydrogen and helium radiations at 96° from the north point of the Sun. The lines, with a narrow slit, had the form of a widely opened fan; the displacement was greatest on the side toward the red, and corresponded to a radial velocity of 20 km. per second.†

I immediately had recourse to a photographic spectroscope which gave me the radiation of the prominence in the invisible ultra-violet region, and furnished an exact image which could afterwards be examined at leisure. I have the honor to present to the Academy the series of photographs obtained. These are the first photographs which have been made of these curious solar phenomena, which are rare and of short duration.

In the region of the photograph between wave-length 400 and wave-length 360, the radiation of the prominence is remarkable. The H and K lines, attributed to calcium are extraordinarily brilliant; moreover the entire series of ultra-violet hydrogen

* *Comptes rendus*, March 14, 1892.

† Widening of lines may result in part from other causes, for example, a great elevation of temperature; but, as lines which are always narrow under ordinary circumstances, such as the line of helium, were included among those widened, this explanation is not the most probable one. In any case the magnitude of the phenomenon is simply and completely expressed in fractions of wave-lengths or in kilometres.

lines, which is obtained complete* for the first time in the Sun, is clearly shown; it is curious to find this characteristic series of the white stars in the atmosphere of a yellow star. Other lines not before recognized in the chromosphere may be added—the magnesium triplet at λ 383†, and the lines λ 375.93, λ 376.14, λ 368.53, which have not been identified with any known element, and may furnish valuable suggestions to chemists in the investigation of new elementary bodies of low atomic weight.‡

Moreover, the widening observed on the bright lines was also found in the ultra-violet spectrum; in certain parts of the negative a continuous spectrum is shown, which corresponds with the brightest part of the prominence.

At $10^h\ 30^m$ the brilliancy of the prominence had greatly diminished; the lines no longer showed the fan-shaped widening, but they presented a marked inclination as compared with the lines at the center of the disc.

The various parts thus had a different radial velocity, by the strict application of Fizeau's principle; this indicates a vortical motion, at least when the inclination persists for a considerable time. But this question, which is a very important one, will be more fully developed later.

These observations and results show clearly that the region of the great spot is still one of great activity, after an entire rotation; they should be compared with a similar observation made by M. Fényi, director of the Kalocsa Observatory, on Feb. 19, when the spot passed over the western limb.

On March 3 the observations were interrupted in the afternoon by bad weather; but on March 4th and 5th the presence of active incandescent masses at the same point on the limb could still be observed, after the *debris* of the great spot had passed over the eastern limb. Moreover, the surroundings of the spot and the entire disc have been studied by the new photographic method mentioned in a former 'note,' which permits the detection of the incandescent gaseous masses projected on the disc.§ A continuous series of prominences surrounding and preceding the spot, and

* Dr. Huggins' ten lines are clearly shown, and others more refrangible are suspected.

† This triplet, according to the recent investigations of MM. Kayser and Runge, belongs to a hydrogen series other than that of the green group b of magnesium, and even stronger.

‡ The six preceding lines were also obtained in a prominence on Feb. 19, occupying the same region of the Sun on the eastern limb at noon, Paris MEAN TIME.

§ These last photographs have been obtained with the aid of my assistant, M. Mittau.

forming thus a veritable ring on the surface of the Sun, has been obtained in this manner.

On March 3, at the moment of the appearance of the great spot, the curves of the magnetic recorders of the Observatory, which M. Wolf has kindly placed at my disposal, indicated no exceptional deviation of the magnetic needle.

PARIS OBSERVATORY, Paris, France.

THE NEW STAR IN AURIGA.*

AGNES M. CLERKE.

Through the modest medium of an anonymous post-card, an event of high importance to astro-physical science was, on the 1st of February last, announced to Dr. Copeland, the Scottish astronomer-royal. This was nothing less than the outburst of a new star in the Milky Way. Now such apparitions are not too common, and they are always short-lived. About a score of them have been credibly recorded during two thousand years, beginning with the star which, according to Pliny, determined Hipparchus upon the construction of his epoch-making catalogue. And the "modern Hipparchus" received a similar emphatic summons. Tycho Brahe was, on November 11, 1572, rescued from the quagmire of alchemy, and recalled to his true vocation, by the startling splendor of the renowned "Nova" in Cassiopeia. This extraordinary object was, to begin with, as bright as Jupiter, and by a further rise, placed itself, in a few days, well-nigh on a par with Venus at her best. Neither the glare of the Sun at noon, nor the drifting by night of clouds thick enough to conceal every other sidereal object, availed to blot out its scintillating lustre. Yet it has utterly disappeared. Not even Mr. Robert's searching camera can detect, in the place it once occupied, the faintest glimmer of its pristine fires. They are to all appearance extinct, and there is small probability that they will ever be rekindled. The idea, it is true, got abroad, and even still partially prevails, that the star of 1572 had previously manifested itself at intervals of about three hundred years, and might be expected to show once more towards the close of the present century; but it seems to have originated in pure misapprehension of some vague mediæval notices of comets. Kepler, however, enjoyed the privilege of observing, though in a

* *Contemporary Review*, April, 1892. By permission of Leonard Scott Publication Co.

totally different quarter of the sky, a new star scarcely the inferior of Tycho's; and these two have, so far, met no rivals to their surpassing brilliancy.

Our own age has, nevertheless, no reason to complain. It has been on the contrary, exceptionally favored in the unusual number of stellar apparitions presented to it. Half a dozen have been crowded into the comparatively short space of forty-four years, and may, accordingly, all have been witnessed with mature comprehension by many men now living. Eminent among them is Mr. Hind, the discoverer of the first of the series, the "Nova," as such objects are technically called, of 1848, the immediate predecessor of which, separated from it by an interval of 178 blank years, was Anthelm's Nova of 1670. This glaring inequality of apportionment has certainly been for the advantage of science. Astronomers in the last century were ill-equipped for taking advantage of such opportunities, while modern physical appliances are especially adapted for turning them to the best account. They are indeed eagerly welcomed; and the evidence afforded by them is earnestly invoked for the testing of novel theories, and for the decision of various moot questions relative to the constitution of the heavenly bodies. When rapid changes are going on, Nature's secrets are apt to slip out for the instruction of those on the watch for them; and new stars are the intensified embodiment of change. No wonder then that the Edinburgh missive of February, acted as a *reveille* to the astronomical forces in all parts of the northern hemisphere.

The sender turns out to have been a denizen of Auld Reekie, Mr. Thomas D. Anderson, the example of whose success will doubtless kindle the zeal of many another amateur star-gazer. His discovery might indeed have been made a week earlier. Only by degrees, and after several observations, Mr. Anderson came to recognize the novelty of the object sending its straw-yellow beams from a previously empty spot in the southern part of the constellation Auriga. It was found moreover on inquiry to have unobtrusively recorded itself twelve times, from December 10, 1891, to January 20, 1892, on the chart-plates exposed at Harvard College for the purposes of the great spectrographic survey in progress there under Professor Pickering's direction. With the first of these casually secured impressions, its biography begins. No trace of its existence has as yet been pursued further back. Unless totally obscure, it belonged then to the crowd of uncatalogued small stars; and merely swelled by a unit the nameless multitude of the heavens. Nothing indicated the distinction in reserve for it.

For one of its class, however, its growth in light was to an uncommon degree leisurely. Most new stars have leaped upwards from obscurity with bewildering swiftness. They claim as a rule, neither past nor future worth mentioning, and only a brief, if brilliant present. But the star of 1892 attained no strongly emphasized maximum. Although absolutely brightest about December 20, it slowly regained light until February 8, when it was of the fifth magnitude—that is, well within the range of naked-eye vision—entering then upon a gradual, and not perfectly continuous, decline. In aspect it was throughout perfectly stellar. Its rays emanated from a sharp point, and, some incautious remarks to the contrary notwithstanding, were nowise blurred or hazy. And a long exposure photograph, taken by Mr. Roberts with a view to developing possible nebulous surroundings, conclusively demonstrated their absence. A similar result was obtained at South Kensington by Professor Lockyer. To all appearance, then, the object was, and is a star like any other. But let us hear the dictum of the spectroscope in the matter.

The light of Nova Aurigæ, unrolled by prismatic dispersion into a rainbow-tinted riband, presented a dazzling spectacle. Splendid groups of bright lines stood out from a paler background; the red ray of hydrogen, Fraunhofer's C, glowed, as Mr. Espin remarked, like a danger-signal on a dark night; a superb quartet of rays shone in the green; shimmering blue bands and lines drew the eye far up towards the violet; the characteristic blazing spectrum, in fact, of a new star was unmistakably present. Its interpretation left no doubt that hydrogen played a large part in the conflagration; Dr. and Mrs. Huggins at once identified a yellow line with the well-known shining badge of sodium, and more than suspected an adjacent ray to belong to the solar element called "helium;" and a violet line distinctive of calcium imprinted itself strongly on numerous photographs. The substances accordingly ascertained to be glowing in this far-off body, are sodium and calcium, the metallic bases, respectively, of common salt and lime; with hydrogen, the universally diffused gaseous metal indispensable for the production of water. Iron and magnesium are doubtful; but carbon had certainly *not* stamped its sign-manual on the opened scroll of the new star's light.

It was marked, however, by one extraordinary peculiarity in the coupling with dark lines of all the bright rays conspicuous over its entire extent. Each lustrous member of the great hydro-

gen-series carried a black shadow on its *blue* or more refrangible side; the rays of sodium, calcium, and other unidentified substances being similarly attended. The meaning of this strange appearance was evident, if in the highest degree surprising.

The principle by which motion in the line of sight can be detected through its effect upon the spectrum of the moving body, is now fully recognized. The amount, moreover, of the observed change gives the velocity of the motion, and the *sense* of the change tells its direction. Thus the rays, say, of hydrogen, when they proceed from a luminous mass rapidly approaching the earth, are pushed from their standard places towards the blue end of the spectrum, while they shift towards the red when the movement is one of recession. The result is strictly analogous to the variation of pitch perceived by a stationary listener in the steam-whistle of a rushing engine. The sound is rendered acute, because the air-waves are shortened by the advance of its originating source; it sinks, on the contrary, as they are lengthened by its retreat. And so with the waves of light sent out by the stars. They are physically crowded together by a physical advance, and hence become *more blue*: but because their succession is retarded, they become *more red* when a velocity of withdrawal is in question. Astro-physicists can, accordingly, determine whether a celestial object be moving towards or away from the earth, and at what rate, by simply measuring on a photograph the deviation from its normal position of some known line in its spectrum.

But in Nova Aurigæ two amazing circumstances were disclosed by this method of procedure. First, the speed corresponding to the measured displacements was unprecedented; next, it was apparently pursued, at the same time, in opposite directions. The bright lines unanimously showed to the careful scrutiny of Dr. Vogel at Potsdam recession at the extraordinary rate of 420 English miles a second, while their dark comrades testified to an approach of 300. Plainly, then, both sets were not emitted by the same body; and a twofold spectrum, owning a twofold origin, was at once seen to be under observation. The whole range of bright lines, in short, was obviously marked out as the appurtenance of a mass rushing away from the earth, the dark ones matching them, as proceeding from a mass rushing towards it. And the two were separating at the rate of 720 miles a second, or about sixty-two millions of miles a day!

Moreover, these portentous velocities showed, during at least a month, no perceptible slackening. The coupled lines did not tend

to close up, as they should have done if the bodies they served to distinguish relaxed their furious speed, or swerved from their straight course. Hence, these presumably did neither the one nor the other to any considerable extent. They can scarcely then be in mutual circulation: yet a pair of gravitating masses could not possibly have made so close an approach as theirs evidently was, without swaying one another into the description of some kind of orbit. Their orbit, however, may be of the hyperbolic variety; in which case the bodies just now visually conjoined are flying asunder, never to meet again. Their single encounter, if this be so, was what we, in our ignorance, can only describe as casual; and the greater part of their motion must be inherent; it belonged, that is, to themselves, *ab origine*, and was not merely imparted by the pull of their mutual attractive forces. And we should indeed naturally expect the solitary outburst of a "new star" to be associated with precisely such a temporary relationship as comports with hyperbolic traveling. In a permanently organized system, on the other hand, light fluctuations, if they occurred at all, might be looked for periodically. This state of things, in fact, seems actually to prevail in the only known example comparable in any degree with the wonderful star of our present experience. The variable star Beta, in the constellation of the Lyra, has, like Nova Aurigæ, been resolved, through the photographic study of its spectrum,* into a pair, of which one member emits bright, the other shows dark lines on a prismatic background. But here there is clear evidence of revolution in a closed orbit, the bright and dark lines exchanging their relative positions once in nearly thirteen days. Moreover, this same period is observed with strict punctuality by the luminous fluctuations of the star. So that we have here a persuasive argument of identity in nature between continuous stellar variations in brightness, conducted regularly in short periods, and the catastrophic out-break of temporary stars. Nay, we gather a hint that the shape of the orbits traversed by such bodies determines the character of their changes; periodical variability depending upon elliptical movement, ephemeral splendor followed by irrecoverable decay corresponding to a single approach at an excessive velocity, with consequent separation along tracks divergent to infinity.

The star of 1892 has then taught us to regard stellar apparitions as resulting, in some way, from the temporary vicinity of

* Conducted at Harvard College by Mrs. M. Fleming and Miss A. C. Maury under the direction of Professor Pickering.

two rapidly moving cosmical masses. All new stars are, it may safely be asserted, during the brief epoch of their visibility, double stars.* The light that they send us emanates from a twofold source. Their duplicity, however, might not always be patent to observation. For the spectra of the bodies in conjunction could only be separately distinguished if their motion happened, like that of the components of Nova Aurigæ, to be largely directed towards or from the earth. If they advanced and retired *sideways* or *vertically*—terrestrially speaking—the combined powers of the spectroscope and camera could extract from them no sign by which their separate existence might be inferred. Sidereal science is thus indebted to the present unaccustomed inmate of our skies for the disclosure of a fact which, without the aid of a body so happily circumstanced for the gratification of intellectual curiosity, might have remained for ages undivulged.

But the knowledge that incandescence of the kind first analysed by Dr. Huggins in the star of 1866 is due to external influence, leads immediately to a further question as to how that influence is exerted. Direct collisions are not to be thought of. And for this obvious reason, that the impact of two inelastic bodies either brings them to a stand-still, or reduces them to a unanimity of slackened motion. We know but too familiarly what takes place when oppositely rushing trains crash together. They certainly do *not* proceed onward at express speed to their respective destinations. But this is precisely what the components of Nova Aurigæ are doing. They have beyond question met no serious check in their flying careers. No considerable part of their motion has been sacrificed to produce their increase of light. Elementary though the principle be, yet it is not superfluous to insist upon it, that incandescence through collision implies stoppage, partial or entire. Since the evolved light and heat are only transformed motion, both kinds of energy cannot be present simultaneously. They are correlative. One disappears to furnish the other. Unless the motion be arrested, the blaze will not occur. One might as well expect to get a coat without curtailment of the piece of cloth affording the material for it.

Hence the outburst of the new star in Auriga cannot be attributed to an actual bodily encounter of two dark bodies

* The compound nature of all variable stars has been advocated for some years by Professor Lockyer; and the merit of the suggestion should be fully acknowledged, although the "meteoritic hypothesis," of which it formed an integral part, has received a fatal blow from the spectroscopic investigations of Nova Aurigæ.

swiftly traversing space. The hypothesis of a grazing collision has more to recommend it. Yet in this case, too, motion should be sacrificed in strict proportion to the development of luminosity. Unless evidence of retardation should be forthcoming, the supposition of outlying entanglements must be abandoned. The two masses, however, spectroscopically observed to be hurrying past at the daily rate of sixty-two million miles, cannot, one would imagine, have surrendered much of their velocity in the process of gaining enhancement to their brilliancy. There is, indeed, a possibility of a *third* body being present, traveling much more slowly than the others. Dr. Vogel, towards the close of February, observed the bright lines on his photographs to be, not only accompanied by dark ones, but themselves double; and he suggested (though with great reserve) in explanation of the phenomenon, the triplicity of the new star. This too, had, very curiously, been surmised by Dr. and Mrs. Huggins as early as February 3, and, if real, could only, one would think, be due to a division of the gaseous body, analogous to the breaking up of some comets in passing the Sun. Yet the circumstance that the bright line spectrum of Beta Lyræ sometimes appears twofold, warns us not to adopt over-hastily, the hypothesis of physical disruption in combination with arrest of movement in the disrupted body.

Masses of matter may, nevertheless, be excited to luminosity by other means besides that primitive one employed in the tinder-box. But before hazarding a conjecture as to how these might be brought into action, let us see what has been learned as to the nature of the bodies concerned in the transient splendor of our Nova. One of them, as giving a spectrum of bright lines, must be of a gaseous constitution. But it is known to be neither a comet on a vast scale, nor a nebula, by the absence of the quality of light distinctive of each of these classes of object. The yellow, green and blue hydro-carbon bands forming the chief part of cometary radiance were clearly shown by Dr. and Mrs. Huggins to have no place in the spectrum of the star, which included conspicuously, on the other hand, the unbroken hydrogen-series of rhythmically disposed rays, from burning red to invisible ultra-violet. But not one of these has ever been observed in a comet. The characteristic nebular spectrum, too, is entirely unrepresented in the Nova, as the eminent investigators just named were the first to point out;* and although affinities are traceable between

* The two rays nearest to the chief nebular lines have since been identified by Dr. Vogel with well-known solar-chromospheric groups.

its light and that of the so-called "Wolf-Rayet Stars" in the Milky Way, the resemblance is by no means complete. Thus the gaseous component of Nova Aurigæ belongs really to no established category of celestial objects. It is a body either peculiar in itself, or peculiar through its circumstances.

The second, and most likely the principal, member of the pair is less difficult to classify. It is emphatically a Sun, and an exceedingly hot Sun. An enormously high temperature is implied by the strength and compass of its ultra-violet spectrum, photographed February 22, by Dr. and Mrs. Huggins, at Tulse Hill, with an exposure of one hour and three quarters. As regards the proportionate intensity of its actinic rays, it is, in fact, not outdone by Sirius itself. The details, however, of its spectral hieroglyphics bring it nearer to Rigel than to Sirius; and it may accordingly be ranked with the Orion variety of "white stars."

Now there is good reason to suppose that every such body is in a state of powerful electrical excitement, and creates in its neighborhood a very extensive magnetic field. A second body entering this field, and sweeping with prodigious speed across the lines of force traversing it, must then give rise to powerful electrical agitations. And here, perhaps, may be found the chief source of the amazing displays registered by astronomers as "new stars." Gravitational disturbances, too, of the kind that raise tides in terrestrial oceans, but immensely exaggerated in degree, no doubt come in as auxiliaries, and produce, at any rate, notable effects of bodily distortion, if not of bodily disruption; yet the view that the sudden illuminations in sidereal space exemplified by the apparition of Nova Aurigæ result, in some measure, from the inductive action of highly electrified bodies dashing past each other at excessive velocities, may possibly be substantiated by future researches into the nature of the unmeasured forces thus brought into play.

By its situation in the thick of the Milky Way, our present "guest-star" conforms to a rule almost universal in such cases. The significance of that rule cannot be mistaken, for it is too faithfully observed to be accounted for otherwise than by real physical location; and we are thus assured beyond doubt that "new stars" have their proper place among the "clusters and beds of worlds" collected into the zone of dim light spanning our wintry skies. The conditions then reigning there must be such as to favor in a marked degree stellar conflagrations. And two of these conditions are well ascertained. The galactic region, in the first place, is assuredly one of exceptional crowding;

and it is abundantly stocked, in the second, with bodies of a gaseous nature, and showing gaseous affinities. Rapid and vast developments, accordingly, of gaseous incandescence through quasi-encounters between rushing masses, are much more likely, it would seem, to occur within Milky Way aggregations than elsewhere in sidereal space.

The components of Nova Aurigæ must be added to the list of what are called "runaway stars." Their headlong velocities are altogether beyond the control of any gravitational power which can reasonably be supposed to reside in the sidereal system. What other forces may be acting upon them, it were vain to conjecture; we can only hold to the secure conviction that they pursue no random career, and make no purposeless haste. Yet the revelation is none the less startling of the prevalence of so tremendous an agitation of movement within the seemingly rigid collections of the Milky Way. By their inconceivable remotenesss, the visible effects of displacement there are well-nigh annihilated; the telescopic detection of them may demand centuries of refined observation; only the wonderful faculty by which the spectroscope is enabled, irrespectively of distance, to measure movements in the line of sight, has afforded the bewildering vision now unfolded to us of a mêlée of flying bodies in a realm of apparent immobility.

To this realm Nova Aurigæ properly belongs—a realm so far off that light can hardly spend less, and may spend much more, than a hundred years on the journey thence to our eyes. The blaze then, studied by astronomers with such curious results during the last couple of months, occurred undoubtedly before any of them were born; and may very well date as far back in absolute time as the Battle of the Boyne. Agile light-rays have, meantime, been bearing the news of the event across the portentous intervening gulf at the express rate of 186,000 miles a second. A proportionate magnitude must be assigned to the catastrophe. Our own Sun would make a very poor show if removed to the distance of galactic aggregations. It could certainly not be discerned with the naked eye; it might not even have been thought worth registering in any of our hitherto constructed star-catalogues. So that the new star of 1892 may well have attained to one hundred times the solar brilliancy.

The certainty of the novel and striking disclosures obtained from it was in great measure due to the employment of the chemical method. No object of the kind had previously been investigated with the potent aid of the camera, reliance on which

was, in the present instance, amply justified by the upshot. The star was photographed everywhere, under both its simple and its prismatic aspects, on the too rare occasions of favorable weather. The earliest records of its spectrum were secured by Father Sidgreaves at Stonyhurst, and by Professor Lockyer at South Kensington; and the Potsdam series extends from February 14 far into March. From the collation of these various documents, the history of the changes undergone by the remarkable pair of separately invisible bodies, the anomalous relations of which have nevertheless been brought within our sure cognisance, can already be minutely deduced, and may, at any future time, be revised from the higher point of view of freshly acquired knowledge. Thus, stellar science is in none of its various branches, any longer dependent on the fleeting impressions of the fallible human eye. By an unerring process of self-registration, the phenomena it studies are rendered virtually permanent, and can be re-observed at will, long after the immediate witnesses of them have passed away. The application of this powerful engine of research to stars of the temporary class has assuredly borne memorable first-fruits. Their full value can hardly yet be estimated.

A STUDY IN THE VARIATION OF THE SOLAR DIAMETER.*

ORRAY TAFT SHERMAN.

The abnormal variation of the Sun's diameter has been a fruitful field of discussion. The result is summed up by the text writers as (1) the diameter of the Sun itself varies, or (2) the observations are too much disturbed by errors incidental to the solar observation to be profitably discussed in relation to their smaller variations. The first of these statements, save in so far as it becomes gratuitous in the light of our result, we leave without discussion. The second statement may, I think, be confined to the case of the result of a single observer. As far as the disturbances are systematic they tend to remain, as far as the disturbances are accidental they tend to destroy themselves when the work of many observers is gathered into a single mean. We have, therefore, gathered all the observations which could be found. Each has been compared with the value calculated by the gravitational theory. The corrections for each month have been

* Communicated by the author.

meaned, converted into arc, and the means of the year taken. The separate yearly values have then been gathered into a general yearly mean. In taking this general mean, those values depending upon a few observations have themselves been joined into a single mean, so that each element of the final mean should depend upon an approximately equal number of observations. When this was impossible the single observation was made the combining unit. This seemed to leave least arbitrary action to the computer. The yearly means, together with the number of observations and observatories involved, are given in the adjoining table.

In No. 234, Jan. 1891, of *The Astronomical Journal* we have given the corrections to the earth's tabular longitude for each year. The same numbers are given in the fifth column after the year 1809. The bar indicates a change in the solar table employed. In the *American Meteorological Journal* for June 1891, we have shown that the auroral numbers for Southern Europe were so connected with the zodiacal light elongations that a maximum in elongation corresponded with a minimum in the auroral number, and a minimum with a maximum. In the fifth column, therefore, we have given Fritz auroral numbers, as an indication of the condition of the zodiacal light. In remarks we have noted the scattered observations of the zodiacal light. If we compare the maximum in the series of yearly means and longitudinal corrections we find maxima agreeing in the following years: 1810-11, '14, '18, '26, '34, '38, '47, '55, '58, '68 '79, '82-'83. All of these maxima may be at once identified as caused by the zodiacal light crossing the Earth's path. In the preceding year we have maxima in 1766 and '94-'96 which, as may be seen from the auroral column, correspond with maximum elongations of the zodiacal light. These are all the maxima the column of Sun-diameters affords. We find minima in the Sun-diameters agreeing with maxima in the corrections to the solar longitudes in the following years: 1820, '23, '26, '41-'43, '51. The minimum in '62 also corresponds to a maximum Sun-spot effect which is masked in the zodiacal column. The rapid decrease in the Sun's diameter from 1814 to 1826 also corresponds to a period during which the corrections to the solar longitude rapidly increased under the influence of the Sun-spots. These are all the minima there are capable of examination. The evidence of the minimum in 1787 tends toward the same end. All of these maxima in the corrections to the longitude may be identified as Sun-spot effects. We have also in 1811, 1821, 1824, 1828, cases

in which a comparatively rapid increase in the solar diameter corresponds with records of appearances of the zodiacal light. The whole evidence therefore points to one statement. Maxima in the values of the solar diameter are the effect of the disturbances produced by the zodiacal light. Minima, the effect of disturbances produced by the solar spots.

We may readily understand how this should be. The spectrum of the zodiacal light shows us that it is in part at least composed of solid matter. We are unaware of the density of the matter or of the density necessary to deflect a body traveling with planetary velocities, but there is evidence which indicates that a very slight density is sufficient. The first effect of the meeting of the zodiacal light and Earth may be shown to be a decrease in the Earth's orbital velocity followed by a decrease in the Earth's radius, which again is followed by an increase in the Earth's orbital velocity due to its altered position. But if instead of passing out of the zodiacal light the Earth remains immersed, we have a continuing repetition of the cycle. One effect of which is that the solar diameter is constantly larger than the gravitational theory requires. Accepting Weber's electrodynamic law as at least approximately expressing a fact, the effect of the Sun-spot increases the attraction of the Sun and Earth. Increasing the force it increases the orbital velocity, and hence the radius, when the planet moves toward the Sun, but to a slighter degree, if at all, when the planet moves from the Sun. This is further evidenced by the variations of the diameter in orbit, as is shown by the following examples. 1841–'43 is a period during which the Sun-spot is predominant; 1847, a period when the zodiacal light has been but slightly in force; 1855, a period when the Earth has continued immersed in the zodiacal light.

	1841–43		1847		1855	
	′	″	′	″	′	″
Dec., Jan., Feb.,	32	2.18	32	2.91	32	3.65
March, April, May,		2 20		3 62		3 71
June, July, Aug.,		2 18		3 82		3 96
Sept., Oct., Nov.,		1 70		2 60		3 61

Year.	Observatories.	Observations.	Observed semi-diameter. 16′ +	3 yr. mean. Observed correction to tabular longitude.	Fritz auroral number for middle Europe.
			″	″	
1753	1	288	1.79		68
1754	1	309	1.44	1.59	87
1755	1	299	1.54		43
1756	2	408	2.10		65
1757	2	429	1.99	2.09	87
1758	2	320	2.19		83
1759	1	312	2.53		94
1760	2	284	2.40	2.78	98
1761	2	254	3.40		124
1762	1	227	3.39		120
1763	1	238	3.76	3.29	100
1764	1	244	2.72		119[1]
1765	1	157	3.87		69
1766	1	190	3.55	**3.53**	40
1767	2	260	3.18		56
1768	2	252	3.66		64
1769	1	211	3.28	3.43	78[2]
1770	1	199	3.36		71
1771	1	214	2.83		96
1772	1	179	2.98	2.70	79
1773	1	192	2.29		96
1774	1	173	2.42		150
1775	1	193	2.39	2.20	88
1776	1	188	1.80		58
1777	1	219	1.21		102
1778	1	217	1.58	1.93	152
1779	1	145	2.00		93
1780	1	176	1.91		130
1781	1	224	1.45	1.52	91
1782	1	181	1.19		103
1783	1	230	1.50		89
1784	1	267	1.36	1.61	85
1785	1	251	1.96		149
1786	1	253	1.20		172[3]
1787	1	210	1.15	**1.16**	**168**
1788	2	282	1.14		161
1789	1	249	1.61		134
1790	1	217	1.46	1.81	115
1791	1	211	1.35		109
1792	2	217	2.06		36
1793	2	252	2.01	**2.10**	**35**
1794	2	388	2.24		36
1795	2	369	**3.30**		**39**
1796	2	387	2.10	**2.15**	63
1797	2	307	1.05		35
1798	2	352	1.73		29
1799	2	344	2.35	2.02	6
1800	3	443	1.99		6
1801	3	542	1.79		7
1802	3	558	1.91	1.99	11[4]
1803	4	538	2.28		8
1804	4	924	2.49		12
1805	4	848	2.77	2.74	22[5]
1806	4	593	2.95		8[6]
1807	4	716	3.16		6
1808	5	563	3.18		2
1809	4	530	2.80	+ 0.63	1
1810	3	471	3.11	**+ 2.65**	1
1811	3	493	**3.71**	+ 1.65	0
1812	3	509	3.37	+ 0.27	0[7]
1813	4	586	3.53	+ 2.12	2
1814	4	803	**4.32**	**+ 2.89**	6
1815	5	806	3.92	+ 2.69	2
1816	6	806 +	3.00	+ 2.98	4
1817	6	879 +	3.27	+ 3.09	26
1818	6	825 +	**3.28**	**+ 3.88**	**8**
1819	7	786 +	2.63	+ 3.89	15
1820	7	849 +	**2.18**	**+ 4.92**	8
1821	4	434 +	2.70	+ 4.40	5[8]
1822	4	421 +	2.37	+ 4.40	3
1823	6	578 +	**1.39**	**+ 4.55**	1[9]
1824	6	709 +	**1.52**	+ 3.06	8
1825	7	789 +	1.36	+ 3.89	26
1826	5	549 +	**0.86**	**+ 5.12**	29
1827	7	601 +	0.97	+ 4.42	37[10]
1828	8	667 +	1.20	+ 6.11	47
1829	7	702	1.26	+ 4.09?	62
1830	6	708	1.26	+ 4.04?	103
1831	6	1021	1.26	+ 8.56?	69
1832	6	1035	1.34	+ 7.49?	20
1833	7	1104	1.40	+ 0.83	27
1834	7	1135	**1.50**	**+ 2.32**	**14**
1835	8	1222	1.44	+ 2.31	15
1836	8	1090	1.32	+ 1.29	23
1837	9	1510	**1.22**	**+ 1.56**	56
1838	8	1170	1.48	+ 1.96	50[11]
1839	8	998	1.37	+ 1.53	85
1840	9	1178	1.55	+ 0.53	76
1841	9	799	**1.14**	**+ 1.73**	63
1842	12	1375	**1.13**	**+ 1.62**	79
1843	11	1172	**1.13**	**+ 1.68**	68
1844	10	1084	1.40	+ 1.58	66
1845	9	850	1.52	+ 0.88	76
1846	8	786	1.87	+ 1.11	80
1847	8	1126	**1.94**	**+ 1.23**	87
1848	7	744	1.73	+ 0.55	129
1849	8	636	1.62	+ 1.63	100
1850	8	570	1.52	**+ 1.89**	89
1851	6	563	**1.29**	+ 1.58	101
1852	6	620	1.35	+ 1.35	138
1853	5	570	1.66	+ 1.66	116
1854	5	609	1.66	+ 2.39	59
1855	6	667	**1.79**	**+ 2.81**	**40**
1856	5	814	1.52	+ 0.18	43
1857	6	1177	1.43	+ 0.03	20
1858	6	1077	**1.53**	**+ 0.35**	66

Year.	Observatories.	Observations.	Observed semi-diameter. 16′ +	Observed correction to tabular longitude.	Fritz auroral number for middle Europe.	Year.	Observatories.	Observations.	Observed semi-diameter. 16′ +	Observed correction to tabular longitude.	Fritz auroral number for middle Europe.
									″		
1859	5	683	1.26	+ 0.54	91	1873	5	626	1.83	− 0.38	158[15]
1860	8	523	1.23	− 0.17	78	1874	5	734	1.55	− 0.23	101
1861	8	890	1.27	− 0.29	83	1875	5	737	1.32	− 0.24	87
1862	9	868	1.03	− 0.41	99[12]	1876	5	749	1.35	− 0.88	72
1863	8	1107	1.12	− 0.55	96	1877	4	352	1.46	− 0.92	69
1864	9	1282	1.28	− 0.30	93	1878	4	332	1.31	− 0.97	85
1865	9	1293	1.48	− 0.14	109[13]	1879	3	421	1.57	− 0.16	67
1866	8	1197	1.32	+ 0.63	105	1880	4	550	1.53	− 0.44	29
1867	8	958	1.45	+ 0.71	90	1881	4	590	1.43	− 0.42	53
1868	8	1007	1.50	+ 0.45	70	1882	4	548	1.26	− 0.07	64
1869	7	615	1.20	+ 0.21	113	1883	4	708	1.57	− 0.60	
1870	6	799	1.33	+ 0.19	143	1884	3	596	1.12	− 0.77	
1871	5	710	1.52	+ 0.40	159	1885	3	241	1.14	− 0.82	
1872	5	713	1.47	− 0.22	140						

[1] Zodiacal light (Perigee). [2] Zodiacal light (Dicquemon). Zodiacal light (Flanzeno). [4] Zodiacal light (Humboldt). [5] Zodiacal light (Huth). [6] Zodiacal light (Bode) (Homer). [7] Zodiacal light (Bode). [8] Zodiacal light (Swiadecki). [9] Zodiacal light (Bode, Olbus). [10] Zodiacal light (Urstphal). [11] Zodiacal light secondary maximum. [12] Maximum Sun-spot effect. [13] Secondary zodiacal light. [14] The zodiacal light crossed the Earth's path though not a maximum.

THE TEMPERATURE OF THE SUN.*

H. LE CHATELIER.

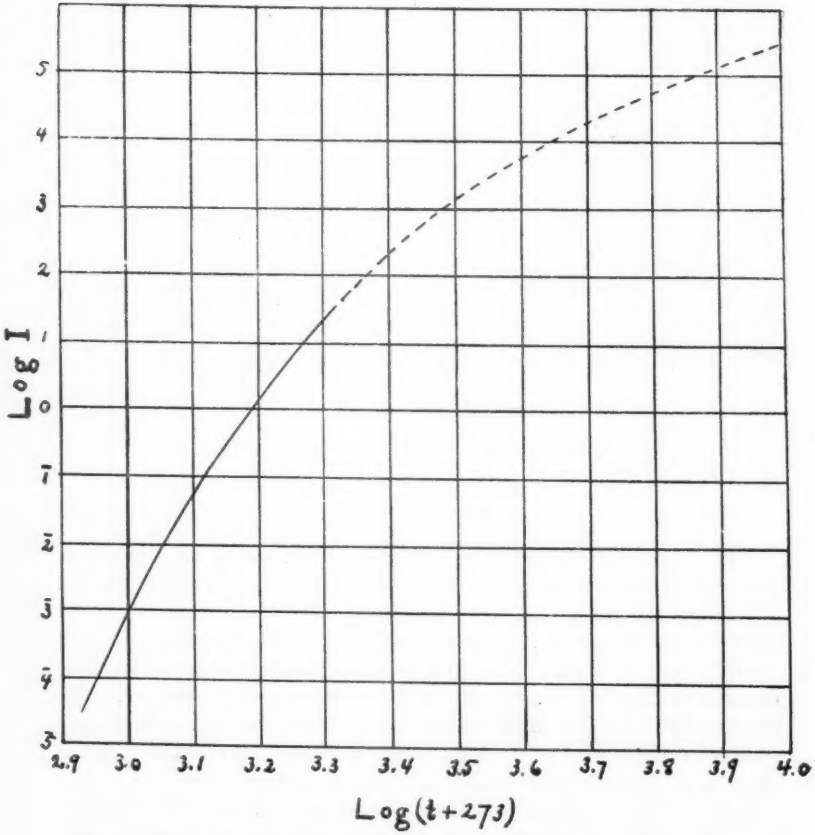
The numerous attempts which have been made to determine the temperature of the Sun have led to the most discordant results; the figures given up to the present time have varied from 1500° to 5,000,000°. The method employed, however, has always been the same (that of Pouillet), and the experimental determinations have always been sufficiently concordant. The divergencies in the final result arise solely, as M. Vicaire has pointed out, from the different laws adopted to connect the radiation of incandescent bodies with their temperature.

Newton's law, which holds only for an interval of a few degrees, gives for the temperature of the Sun millions of degrees. Dulong's law, which is only exact over a range of 150° at most, gives 1500°. Rosetti's law, established by experiments made between 0° and 300°, gives 10,000°.

The degree of confidence which determinations obtained by

* *Comptes rendus* (Paris), March 28, 1892.

means of such extrapolations merit, necessarily increases very rapidly with the magnitude of the temperature interval within which the law of radiation has been submitted to the control of experiment. My investigations, which embrace an interval of 1100° (700° to 1800°), that is to say, four times greater than the most extensive of the experiments here referred to, ought to lead to more certain conclusions.



The intensity of the red radiations emitted by an incandescent body, the emissive power of which is equal to unity, may, according to my experiments, be represented by the formula,*

* The numbers which I have given in my former communication were obtained by graphical interpolation. It is preferable to employ the formula, which causes the intensities given for the temperatures 600° and 700° to be modified a little.

$$I = 10^{6.7} \cdot T^{\frac{3210}{T}}.$$

The following table gives the result of my measures:

Intensities observed.	Temperatures Measured.	Temperatures Calculated.	Differences.	Intensities observed.	Temperatures Measured.	Temperatures Calculated.	Differences.
0.00038	680	671	+ 9	0.06	980	982	− 2
0.00074	700	702	− 2	0.105	1020	1026	− 6
0.002	760	755	+ 5	0.19	1080	1078	+ 2
0.0056	810	814	− 4	0.67	1220	1205	+ 15
0.0054	820	817	+ 3	1.18	1270	1265	+ 5
0.01	860	853	+ 7	6.4	1495	1490	+ 5
0.034	940	939	+ 1	1.49	1775	1757	+ 18

The accompanying curve gives, in the unbroken portion of the line, the reproduction of the experimental results, and in the broken portion the extrapolation necessary to reach the temperature of the Sun.

The measure of the intensity of the solar radiations has been made with the photometer which I employed in my previous pyrometric investigations. Three concordant series have given 120,000 for the intensity of the red radiations reaching the Earth (outside of its atmosphere) from the Sun. I give below the most complete of these series:

Observation on March 19, 1892.

Hour.	Elevation of the Sun.	Intensity.	Hour.	Elevation of the Sun.	Intensity.
2^h m	35° ′	83000	4^h 40^m	14° ′	35000
3	38 30	73000	5	10 30	31000
3 30	25	66000	5 15	8 15	22000
4 12	18	56000	5 25	7	15000
4 30	15	42000			

The intensity of 125,000 which results from these figures indicates an *effective* temperature of 7600°. As M. Violle has proposed, I call the effective temperature of the sun that temperature which a body of emissive power equal to unity must have in order to send us radiations of the same intensity as the Sun. The actual temperature of the photosphere is higher, for a part of its radiations are absorbed by the less highly heated solar atmosphere, and perhaps also, although this seems hardly probable, because the emissive power of the Sun may be less than unity.

It does not seem to me that the uncertainty which attends this temperature of 7600°, on account of errors which may affect the law of radiation, can exceed one thousand degrees.

SOLAR OBSERVATIONS DURING THE FIRST QUARTER OF 1892.*

P. TACCHINI.

The season has been very unfavorable for observations. For the spots and faculæ the number of days of observation has been 56, *i. e.*, 19 in January, 19 in February and 18 in March. The following are the results:

1892.	Relative Frequency		Relative Size		Number of spot-groups per day.
	of spots.	of days without spots.	of spots.	of faculæ.	
January	19.63	0.00	79.79	56.58	5.90
February	23.31	0.00	153.61	60.28	5.16
March	13.21	0.00	61.67	86.39	4.28

A considerable increase over the preceding quarter is thus shown. Three periods of greater frequency and extent of spots correspond with the intervals January 16–24, February 5–18 and March 20–25.

We have obtained the following results for the prominences:

1892.	No. of days of observation.	Prominences.		
		Mean number.	Mean height.	Mean extent.
January	13	6.39	39.6	1.6
February	13	7.00	36 0	1.6
March	14	8.14	36.4	2.3

The difference from the preceding quarter is slight, but I believe that the phenomena of the prominences may be considered to have been a little more marked than during the preceding quarter. It should be noticed that while a well-marked maximum of spots occurred in February, the prominences do not show any great differences in the series, and that a maximum took place in March, as was also the case with the faculæ. For the spots, on the contrary, there was a minimum in the month of March.

R. OSSERVATORIO DEL COLLEGIO ROMANO,
Rome, 21 April, 1892.

ASTRO-PHYSICAL NOTES.

All articles and correspondence relating to spectroscopy and other subjects properly included in ASTRO-PHYSICS, should be addressed to George E. Hale, Kenwood Astro-Physical Observatory, Chicago, U. S. A. Authors of papers are requested to refer to page 544 for information in regard to illustrations, reprint copies, etc.

M. Lecoq de Boisbaudran's Observations on the Electric Spectra of Gallium.—In the *Comptes rendus* (Paris) for April 4, M. Lecoq de Boisbaudran has an interesting Note on his recent studies of the spectrum of gallium. The spectrum obtained when the uncondensed spark produced by a long-wire coil passes between

* Communicated by the author.

a metallic electrode and the surface of a solution of chloride of gallium, comprises two characteristic violet lines and a broad, nebulous green band, which seems to be due to the oxide of gallium. If metallic gallium is employed, and a condenser used with the coil, the spectrum becomes much more complicated, and the green band disappears. A small condenser of a few square centimetres surface is sufficient for the purpose. The spark was observed successively in air, carbonic acid gas and hydrogen, in order to be certain that none of the gallium lines were masked by the brilliant lines in the spectra of the enveloping gases. The difficulty of securing perfectly dry gases, and the widening of the red line of hydrogen (C), leaves some doubt as to the exact condition of things in its immediate neighborhood. A list of the wave-lengths of seventeen lines and bands observed is accompanied by notes on various physical characteristics. On taking the spark from a short-wire coil between electrodes of metallic gallium, the spectrum was found to differ materially from that described as produced by the long-wire coil with condenser. Only six important lines were now seen; one of these, very faint in the condensed spark, had become easily visible; another was reduced from a bright to a feeble line; a third appeared in the green, which had not been seen at all with the condensed spark. M. de Boisbaudran remarks in conclusion, "as similar changes occur, in a more or less remarkable manner, with nearly all bodies, it is very necessary to define the conditions under which electric spectra are obtained."

The Aurora of April 25, 1892. Contemporaneously with the return of the great spot (February, 1892) to the eastern limb of the Sun, there appeared an unusually brilliant aurora for these latitudes. I first observed a massing of pale diffuse yellow light 40° W. of N. at 10:5 P. M. (Greenwich M. T.) with two paler streamers of the same color rising from that point perpendicularly to the horizon, and reaching a height of 40°. At 10:15 P. M. the mass of light on the horizon became of an intense pea-green, and the two parallel streamers became so brilliant as to fill in the interspace a fine solid shaft with a somewhat dimmer axis resulting, the structure reaching 50° in height. During and after this, the bank of green light, already extending from 40° to 15° W. of N., gradually passed round the horizon towards N. E., whilst a few faint streamers, at an angle of 80° to 75° to the horizon, brought the display in the N. W. to a close, the inclination being westward.

In the meanwhile, the horizon light had reached as far as 40° E. of N., at which point another maximum occurred at 11:15 P. M., much less brilliant than the former one, but more permanent. Here three or four pale streamers reached up perpendicularly to 50°, dying off at 11:25 P. M. after a few minutes of brighter display.

The diffused light which had been gathering more intensely than ever on the north horizon now became very vivid and continued so, whilst the point of the first display, 40° W. of N., rapidly gained light, until it equalled, if not surpassed that at the N. At 12:20 A. M. short, well defined and quickly-changing shafts of pale green light shot up from an intense bed of pale grass-green at 40° W. of N, those furthest to the W. appearing to radiate from the centre of the patch. At 12:25 A. M. a massive column, whose width subtended 12° to 15°, ran clear up to the zenith, and almost instantly the quadrant between N. W. and N. E. sent up broad, bright, converging bands of the same green color, there only being two less brilliant streamers about 40° E. of N. which failed to reach the zenith, and which made an angle of about 80° to the horizon, inclining eastwards. The light on the horizon underlying these two streamers was likewise less

bright than elsewhere. The whole quadrant was now ablaze to the zenith small white clouds in the zenith taking on a complementary red. That the red was complementary was easily ascertained by looking at them immediately after closing the eyes for a few seconds. I read the time from a dark-faced watch at this time as 12:25 A. M. with perfect ease. During the maximum the horizon-light in the north oscillated vigorously in a horizontal direction for some 15 seconds, with an effect one might obtain by observing many fluctuating parallel surfaces in their own plane, or closely-packed transparent strata under similar conditions. I will not say that corruscation was connected with this oscillatory movement, but I think so.

This last display brought the aurora to a climax and a close, for it had barely subsided when I noticed a general mist covering up what had been till then a clear starry sky, and within 15 minutes from the disappearance of the auroral light, the sky was perfectly overcast, and very fine rain falling.

Stretford, Lancashire, England. J. MACLAIR BORASTON.

Solar Halo and Mock Suns.—On the 30th April, a brilliantly clear day, a fine halo, 50° diameter inside measure, accompanied the Sun from 2:45 P. M. (G. M. T.) to sunset. From S. W. through W. to N. W. the sky was pencilled with delicate parallel striæ of cirro-stratus, the general lie of which was at an angle of 3° to 4° to the horizon, the inclination being northwards. A line passing through the halo and Sun at the same angle bisected a Mock Sun at each point of intersection with the halo. The image on the S. side, as well as the S. side of the halo itself, was brighter than those opposite, though the image on the N. side was better defined. Each image had a corona of diffused light, elongated laterally. The circle enclosed by the halo was of a dusky slate, the Sun being of a dazzling silver white in the centre. The interior edge of the halo was red, the outer edge blue, and beyond the latter was a broad, bright circle of light blue shading off gradually into the darker blue of the surrounding sky.

Throughout the evening a four-days' Moon was encircled by an orange-red corona, coincident with the Moon's edge on the dark limb, and extending a lunar diameter from the bright limb. The earth-shine was coppery.

Stretford, Lancashire, England. J. MACLAIR BORASTON.

Wolsingham Observatory, Circular No. 32.—The star DM. + 55° 1870, XVI^h 39^m 49^s, + 55° 12′ ('55), 9.2, was found 7.3; 7.7, April 26; 29. Variable Spectrum like Mira. T. E. ESPIN.

Kayser and Runge on the Spectra of the Elements.—Professor C. Runge's article on another page "On the Line Spectra of the Elements" is from the pen of one well qualified by long investigation to write on a subject of so great importance. The recent appearance of Part V of Professors Kayser and Runge's series of papers, "Ueber di Spectren der Elemente," is an evidence of progress in a research which promises much toward our knowledge of molecular vibrations. In this last contribution the arc spectra of copper, silver and gold are described in detail. A concave grating of 21 ft. radius and 20,000 lines to the inch (ruled on Professor's Rowland's second machine), made it possible to secure photographs 20 inches in length with a single exposure. It is a pleasure to see the wave-lengths expressed in six figures, and the limiting error given for each line. Other investigators would do well to profit by this example. As in the case of the alkali metals, two secondary series of double lines with constant oscillation differences were found for copper and silver; the principal series seemed to be missing, though a strong double line was noted as possibly forming the first member. No series were found in the case of gold.

XUM

The Spectrum of Comet *a* 1892 (Swift).—This morning I obtained an observation of this bright comet with the spectroscope of the 36-inch equatorial. The spectrum is at present of the usual type. The spectrum of the nucleus is apparently continuous and visible from about *C* to *G*. It was made quite broad by the long telescope, and I observed that it was more sharply defined on the east edge than on the west [the slit was parallel to the equator]. Later it was seen that the sharp edge and the diffuse edge corresponded to the sides of the nucleus from and towards the tail.

The three well-known yellow, green and blue bands were present, their intensities being approximately in the ratio 1 : 6 : 2. Their lower edges were quite sharply defined. When the slit was narrowed to 0.004 inches, the bright line on the lower edge of the green band became exceedingly sharp, and could be bisected by the micrometer thread with extreme accuracy. There was apparently no condensation at the point where it crossed the continuous spectrum, except what would be expected from the superposition of the two, thus showing that the bright line is characteristic of the coma rather than of the nucleus.

The wave lengths of the less refrangible edges of the bands were obtained by comparison with nine lines in the iron and magnesium spark-spectra. A 60°-prism was used, there being insufficient time before dawn to change to a higher dispersive power. However, the distances to be measured were short, especially for the middle band, and the settings could be made very accurately; and I give the results to four and five places, as below:

$\lambda = 5630$	$\lambda = 5170.4$	$\lambda = 4722$
31	.4	24
28	.5	22
$\lambda = 5630$	$\lambda = 5170.4$	$\lambda = 4723$

These wave-lengths are not corrected for relative motion of the earth and comet.—*The Astronomical Journal.* W. W. CAMPBELL.

Mt. Hamilton, 1892 April 6.

Photography of The Ring Nebula in Lyra.—Father Denza has recently made a very successful photograph of the ring nebula at the Observatory of the Vatican, and in "*l'Astronomie*" for May a heliotype reproduction, enlarged 78 diameters from the original negative, may be found. Not only is the central star very prominently shown, but there seems to be evidence in addition of a much fainter one, also within the annulus. It is remarkable that this star (if it certainly is a star) should have been obtained by the Roman astronomer with an exposure of only $1^h\ 50^m$, while M. Trépied, using a similar telescope at Algiers in August, 1890, found no certain trace of such an object with an exposure of 6 hours.

A Large New Nebula in Auriga.—The following note by Professor Schaeberle is taken from Pub. A. S. P., No. 22:

On receiving the announcement, February 6th, of the discovery of Nova Aurigæ, Professor Holden requested me to use the Crocker telescope for photographic observations on this star. The same day (February 6th) the Willard lens was therefore strapped to the 6-inch Clarke equatorial, and a series of exposures made that evening. Similar observations have been made on every clear night up to the present time.

On a plate which I exposed for 150^m on the evening of March 21st, I find a large and apparently new nebula in R. A. $5^h\ 9^m.5$, Dec. $+34°\ 10'$. The north preceding part of this nebula is in the form of a comparatively slender ray which seems to have its origin in the star W. B. 5^h, No. 151. This ray gradually

widens—the northern boundary running in an easterly direction for a quarter of a degree or more; the southern boundary runs in a southeasterly direction, passing just a little to the north of the star W. Br., 5^h, No. 162 (a naked-eye star) around which it appears to bend, and then takes a southerly course extending more than a quarter of a degree beyond this star.

In a southeasterly direction the length of the nebula visible on the plate is more than half a degree, while its width varies from a few minutes of arc, at the star No. 151, to twenty or more minutes opposite the star No. 162.

A photograph taken February 27 which I exposed for 90^m shows, less conspicuously, the same object. Since the 21st the weather has been unfavorable so that the possibility of seeing the nebula *visually* is still a question to be decided.

Lick Observatory, March 23, 1892. J. M. SCHAEBERLE.

P. S.—On the evenings of March 24 and 25 I made exposures of 200^m and 195^m respectively. These plates plainly show that the nebula joins the above mentioned stars W. B. 5^h, Nos. 151 and 162. Prints made so as to show only the brightest parts of the nebula reveal the following structure:

A narrow stream of nebulosity issues from the star No. 151 on the east side; a short distance from this star the stream divides into two parts; one running in a southeasterly direction passing the star No. 162 at a distance of two or three minutes of arc, then suddenly curving in towards the star, which it joins in the southeast quadrant. This stream is inclosed by the other branch, which first runs in a more easterly direction until it reaches a point northeast of the star No. 162, where it suddenly curves in towards this star and joins it in nearly the same position-angle as the first branch. From this same point of junction a third stream runs from the star in a southerly direction for a distance of 5′ or more and then turns towards the east. On the original plates several very faint nearly equidistant bands of luminosity are shown in the northern part of the nebula. Taken as a whole a certain resemblance to the Orion nebula is apparent.

J. M. S.

The Portrait Lens in Stellar Photography.—While the above note sufficiently indicates the important part played by the portrait lens in astronomical photography, the varied and valuable results recently obtained by Dr. Max Wolf at Heidelberg with the same means are even more striking. Although Dr. Wolf's portrait lens is only 2½ inches in aperture, he has not only discovered new nebulæ on his long exposure photographs, but new minor planets as well, and several meteors which crossed the field of view left perfectly distinct records of their flight. Dr. Wolf is to be congratulated on the rapid progress he is making in this new field of work.

On the Photography of Colors, by M. G. Lippmann. 1. In the first communication on this subject which I had the honor to present to the Academy, I said that the sensitive films which I then employed were lacking in sensitiveness and isochromatism, and that these defects were the principal obstacles to the general application of the method which I have devised. Since then I have succeeded in improving the sensitive film, and although much yet remains to be done, the new results are sufficiently encouraging to allow me to present them to the Academy.

2. I obtain very brilliant photographs of the spectrum on albumino-bromide of silver films rendered orthochromatic by azaline and cyanine. All the colors appear at once, even the red, without the interposition of colored screens, and after an exposure varying from five to thirty seconds. On two of the plates the colorsby transmission are very clearly complementary to those perceived by reflection.

3. Theory indicates that the compound colors which adorn natural objects

should be obtained in photography in the same way as the simple colors of the spectrum. It is none the less necessary to verify the fact experimentally. The four plates which I have the honor to submit to the Academy faithfully represent objects of various kinds: a stained glass window of four colors, red, green, blue, yellow; a number of flags; a plate of oranges surmounted by a red poppy; a many-colored parrot. They show that the form is obtained as well as the colors. The flags and the bird required five or six minutes exposure in the electric light or sunlight. The other objects were made with several hours exposure in diffuse light. The green of the foliage, the gray of the stone in a building, are perfectly brought out on another plate, the blue of the sky, however, became indigo. It now remains to perfect the orthochromatism of the plate and to considerably increase its sensitiveness. (*Comptes rendus*, April 25, 1892.)

Magnesium as a Source of Light—In an interesting paper on this subject in the *American Journal of Science*, April, 1892, Mr. Frederick J. Rogers sums up the results of his investigation as follows:

1. The spectrum of burning magnesium, as has already been pointed out by Pickering, approaches much more nearly that of sunlight than does the spectrum of any other artificial illuminant.

2. The temperature of the magnesium flame, about 1340° C., lies between that of the Bunsen burner and that of the air blast lamp, although the character of its spectrum is such as would correspond to a temperature of nearly 5000° C., were its light due to ordinary incandescence.

3. The "radiant efficiency" (the ratio of *luminous energy* to total *radiant energy*) is 13½ per cent; a value higher than that for any other artificial illuminant (excepting perhaps the light of the electric discharge in vacuo, for which Dr. Staub of Zürich has found an efficiency of about 34 per cent.)

4. The radiant energy emitted by burning magnesium is about 4630 calories per gram of the metal burned, or 75 per cent of the total heat of combustion; as compared with 15 per cent to 20 per cent in the case of illuminating gas.

5. The thermal equivalent of one candle-power-minute of magnesium light is about 2.4 lesser calories, as against 3.5 to 4.0 for other artificial illuminants.

6. The total efficiency of the magnesium light is about 10 per cent; as compared with .25 per cent (a quarter of one per cent), for illuminating gas.

7. Taking into consideration the greater average luminosity of the rays of the visible spectrum of the magnesium flame, it is certain that *per unit of energy expended, the light-giving power of burning magnesium is from fifty to sixty times greater than that of gas.*

The Magnetic Storm of February in Mauritius.—At a meeting of the Meteorological Society of Mauritius, that took place on April 7, Mr. Meldrum read a short paper on the Sun-spots, magnetic storm, cyclones, and rainfall of February, 1892. The photographs of the Sun that he exhibited, which were taken at the Royal Alfred Observatory from February 5 to 18, showed the very large group of spots, their approximate latitude on the 9th being from 6° to 16° south. Leading on to the occurrence of the great magnetic storm which began at 8^h 55^m on the 13th, he states that its commencement was distinctly recorded on the three curves, the horizontal force suffering the greatest disturbance. Up to 14^h the magnet was in oscillation, the force increasing, and reaching a maximum at 13^h 43^m, after which it began to decrease, the minimum being reached at 0^h 15^m on the 14th. Further abrupt movements occurred at 4^h 30^m on the 14th, the oscillations, as shown by the curves, being very numerous

but at 19^h the magnets became more steady, and were quiet by 3^h on the 15th. The ranges obtained at the Mauritius Observatory were the largest ever recorded there.

Cyclones were not absent during this month. One lasted from the 11th to the 14th, and another from the 25th to the 28th, while a third was also experienced on the 21st and 22d, about 550 miles south of Mauritius. The rainfall for February, as shown by returns from the numerous stations, was from 4.30 to 16.96 inches above the average for periods of 7 to 29 years. At Antoinette the fall for the month amounted to 12.53 inches, while that at Cluny came to 34.37 inches. St. Aubin and Nouvelle France came in for a considerable quantity of rain, the falls in the 24 hours ending at 8 A. M. on the 13th reaching the figures 5.00 and 18.20 inches respectively. Referring lastly to the magnificent displays of auroræ that have been observed both in Europe and America, he mentions that, although at Mauritius the sky was overcast, under similar conditions with respect to solar activity and terrestrial magnetism, a great display was visible in 1872. Mr. Meldrum, in his concluding remarks as to whether "there is a causal connection between solar activity (as indicated by outbursts on the sun) and magnetic disturbances, auroras, cyclones, and rainfall," remarks that with regard to the two former there can hardly be any doubt, but with regard to the two latter he is of opinion that a very close connection does exist, there being a considerable preponderance of evidence in its favor.—*Nature*, May 5, 1892.

On the Periodicity Common to Sun-spots and the Aurora Borealis.—(Extract of a letter from Dr. Terby to M. Faye in the *Comptes rendus* (Paris) March 21, 1892).

"I request of the Academy permission to claim priority on the subject of a question raised by the last aurora borealis and its coincidence with the existence of a very large Sun-spot. Several scientists, among whom I will mention MM. Veeder in America and Marchand in France, no longer hesitate to admit that certain Sun-spots, or, in general, certain disturbed regions of the Sun's surface, are capable of producing on the Earth magnetic perturbations and auroras when the rotation of the Sun brings them to a certain point on the visible disc; from this they have arrived at the conclusion that the *return* of the same solar disturbances, in the same regions, by the effect of rotation, is capable of causing the reproduction of similar phenomena at the surface of the Earth; there would thus be a periodicity of magnetic phenomena and auroras, related to the time of the Sun's synodic rotation.

"I request permission to call attention to the fact that these ideas are only the complete confirmation of those which I expressed in 1883, in a memoir published in the *Bulletins de l'Academie royale de Belgique*, third series, v. VI, No. 7, 1883, entitled: "On the existence and cause of a monthly periodicity of the Aurora Borealis." This paper is based on the study of the solar surface in the photographs obtained at Kew from 1869 to 1871, and on that of the order of succession of the beautiful auroras which appeared at this time, ordinarily at intervals of about a month, the greater part of which I observed myself at Louvain. I agree with M. Marchand in the opinion that the terrestrial phenomena coincide with the passage and *often with the return* of the solar disturbance over the central meridian of the Sun. *It will thus be very interesting to note whether a new aurora borealis is not seen about March 12, after the beautiful phenomenon of February 14 last.*"

"Louvain, March 6, 1892."

It will be remembered that a bright aurora accompanied by a magnetic storm occurred on the predicted date.

On the Connection between Sun-Spots and Magnetic Storms.—The following is from an article on the above subject by Mr. A. C. Ranyard in *Knowledge* for April, 1892:

It is possible that though the Sun itself may not be magnetic, it may act as a magnetic body because it is surrounded by a magnetic envelope or region where its gaseous constituents are precipitated into solid or liquid magnetic particles. During the past year, Professor Dewar has shown that oxygen becomes strongly magnetic when liquefied at a temperature of — 180° Cent. The vapors of iron when precipitated in the comparatively hot lower regions of the corona, would also form a cloud of magnetic fog or dust. There is some evidence, in the forms of the coronal streamers seen in the neighborhood of the Sun's poles, that the coronal particles are magnetic, and tend to arrange themselves along lines of force, as if the whole Sun had a magnetic axis, nearly but evidently not accurately, coincident with the Sun's axis of rotation.

The corona is far from being accurately symmetrical with respect to the Sun's axis of rotation; it is denser in parts, and has projecting rays or structures which extend to a great distance from the Sun, especially in the Sun's equatorial regions. On the above theory we should expect to find the magnetic region similarly unsymmetrical, and a body passing round the Sun, near to the plane of the solar equator, would be subject to very unequal disturbance from the magnetic particles of the corona This seems to tally with the facts observed—for the greatest magnetic storms have generally taken place when a large spot has been seen near to the centre of the Sun's disc. We know very little at present as to the connection between the corona and Sunspots, or as to how far the corona extends—some of its larger structures may extend as far as the earth's orbit, or as far beyond our orbit as the zodiacal light extends. There is no evidence that large coronal structures exist over large Sunspots, but there is evidence of an intimate connection between the general development and arrangement of the parts of the corona and the spottiness of the Sun's surface, as well as between the development of large prominences and Sunspots.

The Great Sun-spot and its Influence.—In a valuable article on the great February Sun-spot in *Knowledge* for April and May, Mr. E. W. Maunder brings forward some important evidence in regard to the connection between Sun-spots and magnetic storms. Mr. Maunder concludes his article as follows:

In a period of nearly nineteen years, therefore, we have three magnetic storms which stand out pre-eminently above all others during that interval. In that same period we have three great Sun-spot displays—counting the two groups of April, 1882, together—which stand out with equal distinctness far above all their similar displays. And we find that the three magnetic storms were simultaneous with the greatest development of the spots. Is there any escape from the conclusion that the two have a real and binding connection? It may be direct, it may be indirect and secondary only, but it must be real and effective.

Consider that the period in question is practically some 6,800 days. A magnetic storm does not last many hours; a Sun-spot soon declines from its greatest development, or soon passes away from the center of the apparent disc. Suppose we take an outside limit, and give a period of two days to a giant spot to exercise its influence, or a magnetic storm to expend its violence; what are the probabilities against 3 out of 3,400 of such periods of the one phenomenon agreeing with 3 out of 3,400 of the other, if they are not related? If 3,400 numbers were placed in one box, and 3,400 more in a second, and one from each box were drawn at a time, what is the chance that the three highest numbers would be drawn from the

one box, simultaneously with the three highest from the other, each to each, if the matter had not been pre-arranged? Indeed we might legitimately call the coincidence of April, 1882, a double one, and ask the odds against the four highest numbers from each box being so drawn.

Between Sun-spots and storms of the second magnitude it is more difficult to make a satisfactory comparison, because it is not so easy to frame a satisfactory definition as to what constitutes a secondary disturbance. Nevertheless the following brief table of large Sun-spots seen since the beginning of 1881 which were coincident with considerable disturbances may prove of interest. The spotted area is given in millions of square miles:

Date.	Spotted Area. Entire Sun.	Spotted Area. Largest Group.	Date.	Spotted Area. Entire Sun.	Spotted Area. Largest Group.
1881. Jan. 31	1295	686	1883. Nov. 1	2100	784
Sept. 12	2089	917	" 19	3682	1600
1882. Oct. 2	2480	1234	1884. March 2	1510	609
" 5	2065	1198	April 24	2348	1510
1883. April 3	1545	607	" 30	1746	897
" 19	2170	670	1885. Jan. 23	1687	592
June 30	3650	2210	Feb. 5	1345	571
July 11	1887	1009	" 13	1569	480
" 29	1425	1264	May 26*	1923	647
Sept. 17*	2017	1263	June 24*	2348	1681
Oct. 16	4730	1733	July 18	1835	504
" 20	1650	1369	1891. Nov. 22*	1966	1371

Some of the above, those marked with an asterisk, may fairly be taken as confirming, though with less definiteness, the conclusion drawn from the correspondences between the greatest spots and the greatest storms. But with the others it is not so. Spots as important have been seen upon the Sun, and the magnets have scarcely fluttered, and storms as distinct have occurred when there have been only few spots, and those but small, upon the visible disc of the Sun. The table is important, therefore, not as adding to the weight of the evidence in favor of the connection between Sun-spots and magnetic disturbances, but as emphasizing a point which must not be forgotten. Though the diurnal and annual changes of terrestrial magnetism conclusively prove the solar influence upon it, though the connection between the general Sun-spot cycle and the general magnetic cycle is clearly established, though even in minor irregularities the two curves closely correspond, and though unusually large Sunspots are answered by unusually violent magnetic storms, we cannot, as yet, proceed further and express the magnitude or character of the magnetic disturbances in terms of the spotted area of the Sun, or of its principal groups at the time of observation. The conclusion to my own mind seems to be that though Sunspots are the particular solar phenomenon most easily observed, we must not infer therefore that their number and extent afford the truest indication of the changes in the solar activity which produce the perturbations we remark in our magnetic needles.

Absorption Spectra of Metallic Films.—In the *American Chemical Journal* March, 1892, Mr. W. L. Dudley describes the methods he has employed in forming very thin films of various metals on transparent surfaces. He remarks as follows in regard to the absorption spectra of the films: "Many of the films which corresponded closely in color to the incandescent vapor of the respective metals were examined carefully as to their absorption spectra by throwing a powerful beam of white light through them. If the same molecular condition existed in the film as in the incandescent vapor, we would expect to have the same absorption. In other words, the dark lines of the absorption spectrum of the film

should coincide with the bright lines of the emmission spectrum of the incandescent vapor. I found in every case, however, that the films gave simply general absorption, no bands or lines being indicated."

The Visible Spectrum of Nova Aurigæ.—The following letter from Professor Campbell has been received just as we go to press. We regret that the photograph has not arrived in time to appear this month, but it will be used in connection with the article on the spectrum of the Nova which will probably be found in our August number.

MOUNT HAMILTON, May 16, 1892.

My Dear Professor Hale:

I send you by express to-day a photographic copy of a drawing of the visible spectrum of Nova Aurigæ. It is based almost wholly on my observations of Feb. 8, Feb. 9, and March 13. One bright line was observed on March 13 which is not shown in the drawing. Altogether there are thirty bright lines whose positions I determined, two bright lines (at 680 and 432) whose positions were not determined, and ten dark lines.

My visual observations have been reduced a month or six weeks, but I have delayed sending them to you in order that I might send the photographic results with them. But they are not yet ready owing to a pressure of other work, to the very great complexity of the photographs, and to the time consumed in determining the best methods of enlarging, measuring, etc. Spectroscopic photography is still in its infancy here, as you know, and it takes time to determine experimentally the best methods.

Having just noticed that a July number of ASTRONOMY AND ASTRO-PHYSICS is not to be issued, I thought it advisable to send you this note explaining the delay. I hope the photograph (positive, on glass) will reach you unbroken.

Yours very truly, W. W. CAMPBELL.

CURRENT CELESTIAL PHENOMENA.

PLANET NOTES FOR JULY AND AUGUST.

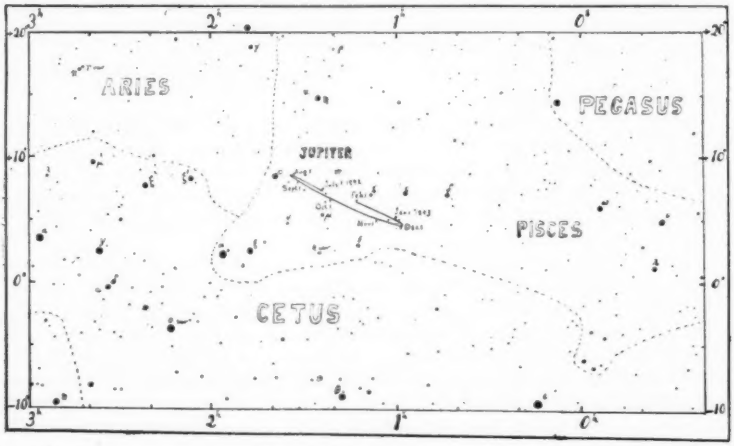
Mercury will be at greatest elongation east from the Sun, 27° 14′, July 29. It will, however, in our latitude set only an hour later than the Sun, so that the conditions will not be favorable for naked eye observations. On August 25, at 9 p. m., central time, Mercury will be at inferior conjunction with the Sun, about 4° south of the latter.

Venus will be at inferior conjunction, about 5° south of the Sun, July 9 at a few minutes past noon, central time. Thirty-seven days later she will reach her greatest brilliancy as "morning star."

Mars will be stationary in R. A. July 6, making the turn in the loop of his path through Capricorn (see chart page p. 439). During these two months Mars will be in very favorable position in all respects excepting, in the northern hemisphere, his low latitude. Opposition occurs August 3 at midnight, when his distance will be only 35,000,000 miles. His apparent diameter will then be 27″. This opposition is the most favorable one for observation since that of 1877, when Professor Hall discovered the two satellites, and it will be a good time for the amateur astronomer to see as much as he can of the markings of Mars' surface.

There will be an occultation of Mars by the Moon on the night of July 11, which will be visible throughout the United States. As seen from Washington

the occultation will begin at $11^h\ 13^m$ P. M. and end at $12^h\ 15^m$ eastern standard time. The Central times of the same would be $10^h\ 13^m$ and $11^h\ 15^m$ P. M. respectively. For other localities than Washington the times would vary by several minutes one way or the other, because of different parallax of the Moon. Mars will be again in conjunction with the Moon, 1° 52′ south, Aug. 3 at 21 minutes past midnight.



PATH OF JUPITER AMONG THE STARS DURING THE OPPOSITION OF 1892.

Jupiter will be in good position for observation in the morning during July and August. He will be at quadrature, 90° west from the Sun, July 15; in conjunction with the Moon, 29′ north, July 16 at $5^h\ 26^m$ P. M., and again, 2′ south, Aug. 13, at $1^h\ 26^m$ A. M. The last mentioned conjunction will be an occultation, as seen from the southern parts of the United States, Mexico, Central America, and the northern part of South America. The accompanying chart shows the path of Jupiter among the stars during the remainder of 1892 and one month of 1893.

Saturn will be too far down in the west for good observing, although he may be seen during the early evening hours of July.

Uranus will also be pretty low for good seeing by the time that twilight ends in these months. Uranus will be in conjunction with the Moon July 30, at $11^h\ 33^m$ P. M., central time. This will be an occultation as seen from the southwestern part of the United States and some of the islands of the Pacific.

Neptune is visible in the morning. He is in Taurus about 5° northeast of the bright red star Aldebaran.

MERCURY.

Date. 1892.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
July 5.....	8 12.7	+ 21 49	5 39 A. M.	1 15.7 P. M.	8 52 P. M.
15.....	9 19.4	16 37	6 31 "	1 43.0 "	8 55 "
25.....10	08.2	10 50	7 05 "	1 52.2 "	8 39 "
Aug. 5.....10	39.9	5 29	7 16 "	1 40.7 "	8 06 "
15.....10	41.9	3 30	6 46 "	1 03.4 "	7 21 "
25.....10	16.1	+ 6 14	5 30 "	11 58.3 A. M.	6 26 "

VENUS.

Date 1892.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
July 5.....	7 25.9	+18 15	5 10 A. M.	12 29.0 P. M.	7 48 P. M.
15.....	6 59.8	17 09	4 10 "	11 23.7 A. M.	6 38 "
25.....	6 42.7	16 41	3 15 "	10 27.3 "	5 39 "
Aug. 5.....	6 42.2	16 52	2 30 "	9 43.6 "	4 57 "
15.....	6 56.9	17 17	2 04 "	9 18.8 "	4 34 "
25.....	7 22.1	+17 31	1 49 "	9 04.8 "	4 21 "

MARS.

July 5.....	21 25.7	−20 27	9 48 P. M.	2 26.4 A. M.	7 04 A. M.
15.....	21 23.4	21 40	9 13 "	1 45.0 "	6 17 "
25.....	21 16.4	22 44	8 32 "	12 58.6 "	5 25 "
Aug. 5.....	21 05.0	23 48	7 43 "	12 04.1 "	4 26 "
15.....	20 54.6	24 23	6 56 "	11 14.3 P. M.	3 33 "
25.....	20 47.0	−24 29	6 10 "	10 27.4 "	2 45 "

JUPITER.

July 5.....	1 25.6	+ 7 36	11 52 P. M.	6 25.8 A. M.	12 59 P. M.
15.....	1 29.5	7 56	11 16 "	5 50.3 "	12 25 "
25.....	1 32.4	8 10	10 38 "	5 13.8 "	11 50 A. M.
Aug. 5.....	1 34.2	8 18	9 56 "	4 32.4 "	11 09 "
15.....	1 34.6	8 17	9 17 "	3 53.5 "	10 30 "
25.....	1 33.7	+ 8 10	8 38 "	3 13.3 "	9 49 "

SATURN.

July 5.....	11 44.2	+ 4 09	10 27 A. M.	4 46.7 P. M.	11 06 P. M.
15.....	11 46.8	3 50	9 52 "	4 10.0 "	10 28 "
25.....	11 49.9	3 29	9 17 "	3 33.8 "	9 51 "
Aug. 5.....	11 53.7	3 02	8 39 "	2 54.2 "	9 10 "
15.....	11 57.6	2 36	8 05 "	2 18.7 "	8 32 "
25.....	12 01.6	+ 2 09	7 32 "	1 43.5 "	7 55 "

URANUS.

July 5.....	13 59.9	−11 43	1 45 P. M.	7 01.9 P. M.	12 17 A. M.
15.....	13 59.9	11 43	1 04 "	6 22.7 "	11 38 P. M.
25.....	14 00.3	11 45	12 27 "	5 43.8 "	11 00 "
Aug. 5.....	14 01.0	11 50	11 46 A. M.	5 01.6 "	10 18 "
15.....	14 02.1	11 56	11 07 "	4 22.9 "	9 38 "
25.....	14 03.4	−12 03	10 30 "	3 45.0 "	9 00 "

NEPTUNE.

July 5.....	4 34.7	+20 28	2 09 A. M.	9 38.3 A. M.	5 08 P. M.
15.....	4 36.0	20 30	1 30 "	9 00.3 "	4 30 "
25.....	4 37.1	20 32	12 52 "	8 22.1 "	3 52 "
Aug. 5.....	4 38.2	20 34	12 10 "	7 39.9 "	3 10 "
15.....	4 39.0	20 35	11 27 P. M.	6 57.5 "	2 28 "
25.....	4 39.5	+20 36	10 48 "	6 18.7 "	1 49 "

THE SUN.

July 5.....	7 01.2	+22 42	4 22 A. M.	12 04.4 P. M.	7 46 P. M.
15.....	7 42.0	21 23	4 31 "	12 05.8 "	7 41 "
25.....	8 21.9	19 28	4 40 "	12 06.3 "	7 32 "
Aug. 5.....	9 04.7	16 43	4 53 "	12 05.7 "	7 19 "
15.....	9 42.6	13 46	5 04 "	12 04.1 "	7 04 "
25.....	10 19.6	+10 27	5 16 "	12 01.7 "	6 48 "

Occultations Visible at Washington.

Date 1892.	Star's Name.	Magnitude.	IMMERSION Washington M. T. h m	IMMERSION Angle from N pt. °	EMERSION Washington M. T. h m	EMERSION Angle from N pt °	Duration. h m
July 6	25 Scorpii.....	6.5	12 47	101	14 02	271	1 15
9	B.A.C. 6666.....	6	7 40	41	8 23	324	0 43
11	35 Capricorni....	6	8 50	72	9 55	262	1 05
11	MARS.....		11 05	35	12 07	286	1 02
18	13 Tauri.....	6	12 43	119	13 14	195	0 31
Aug. 2	19 Scorpii.....	5	8 37	59	9 37	334	1 00
5	τ Sagittarii.....	4	6 59	60	8 06	307	1 07
10	B.A.C. 8274.....	7	8 10	77	9 06	233	0 56
15	ν^2 Tauri.....	6	12 41	112	13 20	204	0 39
31	3 Sagittarii.....	5	7 58	70	9 20	294	2 12

XUM

Mr. Marth's Ephemerides of the Satellites of Saturn.

[From *Monthly Notices*, March 1892.].

In this table the times have been changed from Greenwich Mean Time to Central Standard Time. The abreviations *Rh.*, *Te.*, *Di.*, *En.*, and *Mi.*, stand for the names of the satellites Rhea, Tethys, Dione, Enceladus, and Mimas The letters *a*, *b*, *c*, *d*, and *e*, stand for conjunctions of the satellites in order as follows: With the preceding end of the outer ring; with preceding end of planet's equatorial diameter; with center of planet; with following end of planet's diameter; with following end of ring. The letters *n* and *s* signify that the satellite at the time of conjunction is north or south of the point designated by the preceding letter; *Sh.* means that the shadow of a satellite is near the central meridian of the planet; *Ecl. D.* and *Ecl. R.*, the disappearance and reappearance of a satellite at be ginning and end of an eclipse.

June, 1892.			June, 1892.			July, 1892.			July, 1892.		
20	6.8 pm	Te Ecl. R	26	2.4 pm	Mi es	1	3.3 pm	Di n En n	8	1.9 pm	Di an
	7.4	En s Te n		3.7	Rh es			+ 3.6		4.1	Di bn
		+ 1.8		5.1	Di s En n		5.3	Rh s Te n		4.8	Di bs
	7.5	Te n Di s			— 4.0			— 4.3		6.8	Te as
		+ 1.9		6.3	Rh ds		5.6	Di es		8.1	Di Ecl. R
	8.2	Te en		8.3	Mi as		5.7	Te n Titan		9.6	Di en
	9.0	Di ds		9.7	Rh Sh			s — 4.1	9	3.3	Titan dn
21	3.9	Mi en		10.2	Rh bs		5.8	En es		4.0	Te Ecl. R
	4.0	Te Sh	27	3.1	Di an		6.8	Mi an		5.4	Te en
	4.8	Te bs		3.1	En es		7.8	Di ds		7.2	Titan en
	5.5	En en		5.3	Di bn		9.2	Ti an	10	2.1	Te bs
	6.8	Te as		6.9	Mi as		10.3	Di Sh		2.2	Rh as
	9.3	Mi es		9.3	Di Ecl. R	2	7.9	Te es		4.1	Te as
22	4.1	Te Ecl. R		9.5	En as		9.9	Te ds	11	1.3	Te Ecl. R
	5.5	Te en		10.8	Di en	3	6.0	Rh Ecl. R		1.8	Di Ecl. R
	7.7	Rh s Titan	28	5.5	Mi as		6.5	Te an		2.7	Te en
		n — 5.7		6.6	Di s Te s		7.5	Rh en		3.4	Di en
	8.0	En an			+ 4.9		8.5	Te bn	12	1.4	Te as
23	2.2	Te bs		9.7	Di s En s	4	1.6	Di ds		2.0	Rh bn
	2.7	Di ds			+ 3.4		4.8	Di bs		4.5	Di es
	3.7	Titan dn		10.0	Rh an		5.2	Te es		6.7	Di ds
	4.2	Titan as	29	4.2	Mi as		7.0	Di as		6.9	Rh Ecl. R
	5.2	Di Sh		4.5	En an		7.2	Te ds		8.5	Rh en
	6.0	Di bs		9.6	Mi an	5	3.9	Te an	14	5.7	Rh es
	6.5	Mi es		10.8	En en		4.7	Rh es		8.3	Rh ds
	6.8	En as	30	3.0	Di Ecl. R		5.9	Te bs	15	3.7	Di bs
	7.6	Titan en		3.3	En as		7.3	Rh ds		5.9	Di as
	8.2	Di as		3.5	Di en		8.2	Di an	16	7.1	Di an
24	2.2	Te en		6.9	Di n Titan s		9.3	Te Ecl. R		9.3	Di bn
	5.1	Rh Ecl. R			+ 2.6	6	2.5	Te es		10.6	Titan es
	5.1	Mi es		8.2	Mi an		4.5	Te ds	17	12.1	Titan as
	6.5	Rh en		10.2	Te s Titan s		7.4	Te bs	19	3.3	Rh as
	8.0	En s Rh n			+ 2.5		9.2	Te as	21	3.1	Rh bn
		+ 3.1		10.2	Rh s Di n	7	3.4	Te bn		7.8	Rh Ecl. R
	9.3	Di an			+ 5.1		6.6	Te Ecl. R		9.5	Rh en
	9.4	En es		10.6	Ti es		8.1	Te en	23	6.8	Rh es
25	3.8	Mi es		10.8	Titan es		11.0	Rh an		8.4	Rh ds
	8.4	En en	July, 1892.			8	1.9	Te ds	25	3.3	Titan dn
26	1.9	Di as	1	3.6	Rh s Titan					7.1	Titan en
					s — .2						

Configuration of Jupiter's Satellites.

July								July								Aug.							
1		3	4	1	○	2		22		4	3	○	1	2		11		2	1	4	○	3	
2			3	4	○	1	2	23			4	3	○	2	●	12			3	2	○	4	1
3	4	2	1	3	○			24	4	3	2	1	○			13			3	1	○	2	4
4			4	2	○	1	3	25			4	2	○	3	1	14			2f	3	○	1	4
5			4	1	○	2	3	26				1	○	4	2	3	15		2	3	1	○	4	
6			4	2	○	1	3	27					○	2	1	4	3	16				1	○	2	3	4
7	4	2	3	1	○			28			2	1	○	3	4	17					○	1	2	3	4
8		2f	3	4	○	2		29				3	○	1	4	●	18			2	1	○	3	4	
9			3	1	○	2	●	30			3	1	○	2	4	19			2	3	○	1	4	
10		2	3	1	○	4		31		2f	3	2	○	4		20		2f	3	1	○	2	
11			2	○	1	3	4	Aug.								21			3	4	○	2	1	
12			1	○	2	3	4	1				2	○	1	4	●	22	4	2	3	1	○		
13			2f	○	1	5	4	2				1	○	2	4	3	23			2f	4	○	2	3	
14		2f	2	1	○	4		3					○	4	2	1	3	24				4	○	1	2	3
15			3	○	1	2	4	4		2	4	1	○	3			25		4	2	1	○	3	
16			3	○	1	2	4	5		4	3	2	○	1			26		2f	4	2	○	1	
17		3	2	1	○	4		6		4	3	1	○	2			27		3	4	1	○	2	
18			4	2	○	3	1	7		4	3	2	○	1			28			3	4	○	2	1
19			4	1	○	2	3	8		4	2	3	○	●			29		2	3	1	○	4	
20				4	○	2	1	3	9			4	1	○	2	3		30					○	2	1	3	4
21		4	2	1	○	3		10				4	○	1	2	3		31					○	2	3	4	●

XUM

Jupiter's Satellites.

July	1	9	39	P. M.	I	Tr. In.
		10	31	"	I	Sh. Eg.
		11	53	"	I	Tr. Eg.
	3	3	38	A. M.	II	Sh. In.
	4	1	25	"	III	Ec. Dis.
		3	51	"	III	Ec. Re.
		10	49	P. M.	II	Ec. Dis.
	5	1	21	A. M.	II	Ec. Re.
		1	36	"	II	Oc. Dis.
		4	07	"	II	Oc. Re.
	6	10	16	P. M.	II	Te. Eg.
	7	3	42	A. M.	I	Sh. In.
		11	32	P. M.	III	Tr. Eg.
	8	12	52	A. M.	I	Ec. Dis.
		10	10	P. M.	I	Sh. In.
		11	35	"	I	Tr. In.
	9	12	23	A. M.	I	Sh. Eg.
		1	48	"	I	Tr. Eg.
		10	56	P. M.	I	Oc. Re.
	12	1	25	A. M.	II	Ec. Dis.
	13	10	09	P. M.	II	Sh. Eg.
		10	24	"	II	Tr. In.
	14	12	53	A. M.	II	Tr. Eg.
		10	10	P. M.	III	Sh. Eg.
	15	1	25	A. M.	III	Tr. In.
		2	46	"	I	Ec. Dis.
	16	12	04	"	I	Sh. In.
		1	29	"	I	Tr. In.
		2	19	"	I	Sh. Eg.
		3	42	"	I	Tr. In.
	17	12	50	"	I	Oc. Re.
		8	49	"	II	Sh. In.
		10	11	P. M.	I	Tr. Eg.
	20	10	08	"	II	Sh. In.
	21	12	45	A. M.	II	Sh. Eg.
		12	59	"	II	Tr. In.
		3	27	"	II	Tr. Eg.
		11	33	P. M.	III	Sh. In.
	22	2	08	A. M.	III	Sh. Eg.
		10	34	P. M.	II	Oc. Re.
	23	1	58	A. M.	I	Sh. In.
		3	22	"	I	Tr. In.
	24	9	50	"	I	Tr. In.
		10	42	"	I	Sh. Eg.
		12	03	"	I	Tr. Eg.
	28	12	44	"	II	Sh. In.
		3	21	"	II	Sh. Eg.
		3	33	"	II	Tr. In.
	29	3	34	"	III	Sh. In
		10	24	P. M.	II	Ec. Re.
		10	39	"	II	Oc. Dis.
	30	1	05	A. M.	II	Oc. Re.
		3	52	"	I	Sh. In.
	31	1	02	"	I	Ec. Dis.
		10	21	P. M.	I	Sh. In.
		11	42	"	I	Tr. In.
Aug.	1	12	35	A. M.	I	Sh. Eg.
		1	55	"	I	Tr. Eg.
		11	03	P. M.	I	Oc. Re.
		11	07	"	III	Oc. Dis.
	2	1	04	A. M.	III	Oc. Re.
		8	23	P. M.	I	Tr. Eg.
	4	3	20	A. M.	II	Sh. In.
	5	10	29	P. M.	II	Ec. Dis.
	6	12	50	A. M.	II	Ec. Re.
		1	07	"	II	Oc. Dis.
		3	34	"	II	Oc. Re.
	7	2	56	"	I	Ec. Dis.
		9	45	P. M.	II	Tr. Eg.
	8	12	14	A. M.	I	Sh. In.
		1	34	"	I	Tr. In.
		2	29	"	I	Sh. Eg.
		3	46	"	I	Tr. Eg.
		9	25	P. M.	I	Ec. Dis.
		9	30	"	III	Ec. Dis.
		11	49	"	III	Ec. Re.
	9	12	54	A. M.	I	Oc. Re.
		2	56	"	III	Oc. Dis.
		8	57	P. M.	I	Sh. Eg.
		10	13	"	I	Tr. Eg.
	13	1	04	A. M.	II	Ec. Dis.
		3	33	"	II	Ec. Re.
		3	35	"	II	Oc. Dis.
	14	9	47	P. M.	II	Tr. In.
		9	52	"	II	Sh. Eg.
	15	12	13	A. M.	II	Tr. Eg.
		2	08	"	I	Sh. In.
		3	23	"	I	Tr. In.
		11	19	P. M.	I	Ec. Dis.
	16	2	32	A. M.	III	Ec. Dis.
		2	43	"	I	Oc. Re.
		3	49	"	III	Ec. Re.
		8	37	P. M.	I	Sh. In.
		9	50	"	I	Tr. In.
		10	51	"	I	Sh. Eg.
	17	12	02	A. M.	I	Tr. Eg.
		9	11	P. M.	I	Oc. Re.
	19	8	41	"	III	Tr. In.
		10	30	"	III	Tr. Eg.
		3	39	"	II	Ec. Dis.
	21	9	53	"	II	Sh. In.
	22	12	14	A. M.	II	Tr. In.
		12	29	"	II	Sh. Eg.
		2	39	"	II	Tr. Eg.
		4	02	"	I	Sh. In.
	23	1	14	"	I	Ec. Dis.
		9	36	P. M.	II	Oc. Re.
		10	38	"	I	Sh. In.
		11	38	"	I	Tr. In.
	24	12	44	A. M.	I	Sh. Eg.
		1	50	"	I	Tr. Eg.
		10	59	P. M.	I	Oc. Re.
	25	8	17	"	I	Tr. Eg.
	26	10	07	"	III	Sh Eg.
	27	12	18	A. M.	III	Tr. In.
		2	05	"	III	Tr. Eg.
	29	12	30	"	II	Sh. In.
		2	39	"	II	Tr. In.
		3	06	"	II	Sh. Eg.
	30	3	08	"	I	Ec. Dis.
		11	57	P. M.	II	Oc. Re.
	31	12	24	A. M.	I	Sh. In.
		1	26	"	I	Tr. In.
		2	38	"	I	Sh. Eg.
		3	38	"	I	Tr. Eg.
		9	37	P. M.	I	Ec. Dis.

XUM

Minima of Variable Stars of the Algol Type.

U CEPHEI.

R. A.....0h 52m 32s
Decl.....+ 81° 17′
Period.....2*d* 11h 50m

July	3	2 A. M.
	8	1 "
	13	1 "
	18	1 "
	22	midn.
	27	"
Aug.	1	"
	6	11 P. M.
	11	11 "
	16	11 "
	21	10 "
	26	10 "
	31	10 "

ALGOL.

R. A.....3h 01m 01s
Decl.....+ 40° 32′
Period.....2*d* 20h 49m

July	9	4 A. M.
	12	1 "
	14	10 P. M.
Aug.	1	3 A. M.
	3	midn.
	6	9 P. M.
	21	5 A. M.
	24	2 "
	26	10 P. M.

δ LIBRÆ.

R. A.....14h 55m 06s
Decl.....− 8° 05′
Period.....2*d* 07h 51m

July	1	7 P. M.
	15	6 "
	25	1 A. M.

U CORONÆ.

R. A.....15h 13m 43s
Decl.....+ 32° 03′
Period.....3*d* 10h 51m

July	1	1 A. M.
	7	10 P. M.
	14	8 "
	21	6 "
Aug.	8	1 A. M.
	14	11 P. M.
	21	9 "
	28	6 "

U OPHIUCHI.

R. A.....17h 10m 56s
Decl.....+ 1° 20′
Period.....0*d* 20h 8m

July	1	4 A. M.
	1	midn.
	2	8 P. M.
	6	5 A. M.
	7	1 "
	7	9 P. M.
	12	2 A. M.
	12	10 P. M.
	17	3 A. M.
	17	11 P. M.
	22	4 A. M.
	22	midn.
	23	8 P. M.
	27	4 A. M.
	27	midn.
	28	8 P. M.
Aug.	1	5 A. M.
	2	1 "
	2	9 P. M.
	7	2 A. M.

U OPHIUCHI Cont.

Aug.	7	10 P. M.
	12	3 A. M.
	12	11 P. M.
	17	3 A. M.
	17	11 P. M.
	22	4 A. M.
	22	midn.
	23	8 P. M.
	27	5 A. M.
	28	1 "
	28	9 P. M.

Y CYGNI.

R. A.....20h 47m 40s
Decl.....+ 34° 15′
Period.....1*d* 11h 56m

July	2	3 A. M.
	5	3 "
	8	3 "
	11	2 "
	14	2 "
	17	2 "
	20	2 "
	23	2 "
	26	2 "
	29	2 "
Aug.	1	2 "
	4	2 "
	7	2 "
	10	1 "
	13	1 "
	16	1 "
	19	1 "
	22	1 "
	25	1 "
	28	1 "
	31	1 "

Occultations of Stars by the Planets.

[From *Astr. Nach.*, No. 3073.]

	Date		Central Time of Conjunction. h m		Diff. of Decl. ″	Maximum Duration. m	Magnitude of Star.
			STARS NEAR MARS.				
1892.	July	9	8 06	A. M.	+ 19	98	9.0
		24	1 00	A. M.	+ 8	43	9.2
			STARS NEAR JUPITER.				
	July	2	9.8	A. M.	− 67	2.1	9.1
		13	2.4	A. M.	+ 20	2.7	8.9
			STARS NEAR SATURN.				
	Aug.	2	7.8	P. M.	+ 32	1.1h	9.5
		4	4.9	"	+ 115	1.1	9.5
		6	12.5	A. M.	− 60	1.1	9.5
		15	6.8	P. M.	+ 95	1.0	9.1

Brightness of Asteroid No. 324 (Palisa Feb. 24.)—Herr Berberich (*Astr. Nach.* 3088) finds that the Asteroid No. 324, which was of the 11th magnitude when discovered in February last has an average magnitude, at opposition, of 9.7, and that at perihelion its magnitude would be 8. The late discovery of so bright a planet is quite remarkable and is to be explained by the great inclination of its path, 33° 25′, to the equator.

Phases and Aspects of the Moon.

		d	h	m	Central Time.
First Quarter	July	1	8	13	P. M.
Apogee	"	3	6	12	A. M.
Full Moon	"	9	7	44	P. M.
Last Quarter	"	16	7	48	"
Perigee	"	17	8	30	"
New Moon	"	23	5	31	"
Apogee	"	31	12	30	A. M.
First Quarter	"	31	1	45	P. M.
Full Moon	Aug.	8	5	57	A. M.
Perigee	"	12	4	30	"
Last Quarter	"	15	12	37	"
New Moon	"	22	4	59	"
Apogee	"	27	7	18	P. M.
First Quarter	"	30	7	29	A. M.

Twenty-two Asteroids Discovered in 1891.—We take the following data from the *Vierteljahrschrift der Astronomische Gesellschaft*, J. 27, 1:

No.	Name.	Date of Discovery.	Discoverer.	Place.
303	Josephina	Feb. 12	Millosevich1	Rome
304	Olga	Feb. 14	J. Palisa76	Vienna
305		Feb. 16	A. Charlois15	Nice
306	Unitas	March 1	Millosevich2	Rome
307		March 5	A. Charlois16	Nice
308		March 31	Borrelly16	Marseilles
309	Fraternitas	April 6	J. Palisa77	Vienna
310		May 16	A. Charlois17	Nice
311		June 11	A. Charlois18	Nice
312		Aug. 28	A. Charlois19	Nice
313	Chaldea	Aug. 30	J. Palisa78	Vienna
314		Sept. 1	A. Charlois20	Nice
315	Constantia	Sept. 4	J. Palisa79	Vienna
316		Sept. 8	A. Charlois21	Nice
317		Sept. 11	A. Charlois22	Nice
318		Sept. 24	A. Charlois23	Nice
319		Oct. 8	A. Charlois24	Nice
320		Oct. 11	J. Palisa80	Vienna
321		Oct. 15	J. Palisa81	Vienna
322		Nov. 27	Borrelly17	Marseilles
323		Dec. 22	M. Wolf2	Heidelberg
324		Dec. 1	M. Wolf1	Heidelberg

The last two were discovered photographically. No. 324 although discovered earlier than 323 was at first thought to be identical with an older planet, hence was numbered later. The subscript numbers after the name of each discoverer indicates the number of the asteroids discovered by that person.

COMET NOTES.

The weather during the past month has been unusually bad so that we have had but few opportunities to observe the comets. Swift's comet is growing rapidly fainter but is yet a conspicuous telescopic comet with a faint tail about 5° long. It ought to be followed, with large telescopes at least, a couple of months longer. It is moving northeast through the constellation Andromeda. Winnecke's comet reaches its theoretical maximum brightness July 8. It is now quite conspicuous in a five-inch telescope. It is moving rapidly south and west and will pass, during June and July, through the constellations Leo Minor, Cancer, Gemini, and Orion, into Eridanus. The two comets Brooks, 1886 IV, and Tempel, 1867 II, have not been found. We continue the search ephemeris for the former, but there is little probability that it will be found. Denning's comet is in Perseus andmoving slowly southeast. It is extremely faint.

XUM

Orbit of Comet *a* 1892 (Swift).—Since the publication of my orbit of this comet as derived from my own observations in the May number of this periodical, I have made another approximation with the following result.

ELEMENTS.

$T = 1892$ Apr. 6.64066 Gr. M. T.
$\omega = 24^\circ\ 29'\ 29''$
$\Omega = 240\ \ 55\ \ 1$
$i = 38\ \ 42\ \ 19$
$\log q = 0.01162$

O. C. WENDELL.

Harvard College Observatory, May 16, 1891.

Ephemeris of Comet a 1892 (Swift).

(Calculated from Mr. Wendell's elements by H. C. Wilson and Miss F. E. Harpham.)

Gr. M. Noon	App. R. A.	App. Decl	log Δ	log r	Br.
1892 June 16	0 23 08	+ 42 39.7	0.2090	0.1870	0.27
20	29 49	43 49.1	0.2156	0.1996	0.24
24	36 00	44 53.9	0.2217	0.2121	0.22
28	41 35	45 54.3	0.2272	0.2243	0.20
July 2	46 36	46 50.5	0.2321	0.2363	0.19
6	51 02	47 42.8	0.2365	0.2481	0.18
10	54 49	48 31.4	0.2404	0.2596	0.16
14	0 57 59	49 16.3	0.2439	0.2708	0.15
18	1 00 29	49 57.7	0.2470	0.2818	0.14
22	02 18	50 35.5	0.2496	0.2926	0.13
26	03 23	51 09.5	0.2520	0.3031	0.13
30	1 03 46	+ 51 39.5	0.2541	0.3133	0.12

Ephemeris of Winnecke's Periodic Comet 1892.

[From *Astr. Nachr.* No. 3083, continued from page 444.]

Berlin Midnight	App. R. A. h m s	App. Decl. ° ′ ″	log Δ	log r	Br.
1892 July 1	8 22 54	+ 30 37 08	9.1562	9.9477	57.89
2	8 10 40	29 01 43	9.1425	9.9479	
3	7 58 11	27 15 36	9.1294	9.9482	65.04
4	7 45 14	25 18 45	9.1181	9.9486	
5	7 32 03	23 11 36	9.1086	9.9491	73.56
6	7 18 44	20 55 04	9.1010	9.9498	
7	7 05 26	18 30 34	9.0956	9.9506	79.16
8	6 52 15	16 00 02	9.0920	9.9515	
9	6 39 19	13 25 44	9.0920	9.9526	81.62
10	6 26 44	10 50 04	9.0939	9.9537	
11	6 14 36	8 15 25	9.0981	9.9550	80.30
12	6 02 58	5 44 01	9.1044	9.9565	
13	5 51 54	3 17 46	9.1128	9.9580	75.54
14	5 41 25	+ 0 58 05	9.1227	9.9596	
15	5 31 33	− 1 14 00	9.1341	9.9614	68.43
16	5 22 17	3 17 53	9.1466	9.9632	
17	5 13 37	5 13 20	9.1600	9.9652	60.29
18	5 05 31	7 00 24	9.1740	9.9673	
19	4 57 58	8 39 24	9.1884	9.9694	52.17
20	4 50 55	10 10 41	9.2031	9.9717	
21	4 44 21	11 34 43	9.2179	9.9740	44.72
22	4 38 14	12 52 03	9.2327	9.9764	
23	4 32 32	14 03 13	9.2474	9.9789	
24	4 27 12	15 08 48	9.2619	9.9815	
25	4 22 13	16 09 18	9.2762	9.9841	32.60
26	4 17 33	17 05 14	9.2903	9.9868	
27	4 13 11	17 57 02	9.3040	9.9896	
28	4 09 03	18 45 07	9.3174	9.9924	
29	4 05 10	− 19 29 50	9.3306	9.9953	24.00

Berlin Midnight	App. R. A.	App. Decl.	log Δ	log r	Br.
	h m s	° ′ ″			
July 30	4 01 30	− 20 11 30	9.3433	9.9982	
31	3 58 02	20 50 26	9.3558	0.0012	
Aug. 1	3 54 43	21 26 53	9.3678	0.0043	
2	3 51 35	22 01 09	9.3796	0.0073	18.02
3	3 48 34	22 33 25	9.3911	0.0105	
4	3 45 40	23 03 54	9.4022	0.0138	
5	3 42 54	23 32 44	9.4130	0.0168	13.81
6	3 40 13	24 00 06	9.4236	0.0200	
7	3 37 37	24 26 06	9.4338	0.0233	
8	3 35 06	24 50 52	9.4438	0.0265	
9	3 32 39	25 14 29	9.4535	0.0298	10.80
10	3 30 15	25 37 05	9.4630	0.0332	
11	3 27 54	25 58 43	9.4722	0.0365	
12	3 25 35	26 19 30	9.4812	0.0398	
13	3 23 18	26 39 28	9.4899	0.0432	8.59
14	3 21 02	26 58 41	9.4985	0.0466	
15	3 18 48	− 27 17 11	9.5069	0.0499	

Search Ephemeris for Comet Brooks, 1886 IV.

[From Astr. Nach. 3064, continued from page 443.]

	Perihelion, March 31.			Perihelion, April 30.		
	R. A.	Decl.	Light.	R. A.	Decl.	Light.
	h m	° ′		h m	° ′	
July 9	20 27.5	− 42 00	0.32	17 5.7	− 48 52	0.72
19	21 14.7	− 43 35	0.29	17 52.7	− 48 30	0.52
29	21 58.2	− 44 56	0.27	18 01.6	− 47 35	0.37
Aug. 8				18 12.2	− 46 25	0.26
18				18 23.9	− 45 09	0.19
	Perihelion, May 30.			Perihelion, June 29.		
July 9	14 05.8	− 25 46	0.64	12 33.2	− 5 07	0.32
19	14 35.3	− 29 47	0.49	13 01.7	− 10 26	0.29
29	15 06.5	− 32 57	0.37	13 31.9	− 15 28	0.25
Aug. 8	15 38.5	− 35 16	0.27	14 03.6	− 20 05	0.22
18	16 11.0	− 36 53	0.20	14 36.7	− 24 05	0.18
	Perihelion, July 29.					
July 9	11 37.3	+ 6 42	0.16			
19	12 04.1	+ 2 00	0.15			
29	12 32.2	− 2 47	0.15			
Aug. 8	13 01.5	− 7 37	0.15			
18	13 32.1	− 12 16	0.14			

Observation of Saturn.—At 10:30 P. M., Central standard time, I detected one of the satellites of Saturn apparently moving along the needle-like appendage to the planet, which is now presented by the rings. The apparent diameter of the satellite so far exceeded the apparent thickness of the ring, that it gave the appearance of a beautiful golden bead moving very slowly along a fine golden thread. I followed it for an hour during which time the change of position was perceptable without micrometric measurement. At 11:35 A. M. the satellite had moved off the thread and stood with three others to the west of the ring, as seen in the inverting telescope. L. W. UNDERWOOD.

Underwood Obervatory, Appleton, Wis.

At Goodsell Observatory we happened, with some students, to be looking at Saturn with a 16-inch telescope at about $9^h\ 3^m$ P. M. central time on the same night as the above. The satellite Titan was a little below, *i. e* north of, the ring, just in contact with it, on the east side of the planet. The diameter of the satellite appeared to be about three times the thickness of the rings. H. C. W.

NEWS AND NOTES.

Readers of this journal will please remember that our next issue will be for the month of August, as July is one of our vacation months.

During the last month the observers at Goodsell Observatory have been unable to do any work with the instruments on account of rain and persistent clouds.

Total Solar Eclipse, April 15-16, 1893., as presented elsewhere by Professor H. S. Pritchett, Observatory, Washington University, St. Louis, is an excellent setting forth of all the important facts connected with the event. Astronomers everywhere will be interested in this article, not only on account of the local information given, but also in the suggestions made concerning co-öperation of different observing parties along the path of the eclipse. We wish to call special attention to this latter highly important feature of the paper.

The Milky Way by Otto Bœddicker.—The crowded space of our last number made it impossible to speak of the four plates of the Milky Way, in portfolio form made by Otto Bœddicker, and published by Messrs. Longmans, Green & Co., as fully as they deserve. So we call attention to them again.

The drawing was begun in October, 1884, by Dr. Bœddicker, Astronomer at the Earle of Rosse's Observatory at Birr Castle Parsontown, the object being to obtain an accurate representation of the Galaxy as it appears to the naked eye. In an accompanying note, the details of the plan of work are stated quite fully, and will show how faithfully and laboriously it was carried forward to completion. First he copied the maps of Argelander's *Uranometria Nova* which contained parts of the Milky Way. Then excluding all extraneous light he examined a part of the Galaxy until satisfied that he had made out some feature, then by the aid of an incandescent light details observed were inserted on the map. Results were verified on consecutive nights and further details added until a large number of nights was given to one section. The next step was to construct a large chart in stereographic projection to 100° north polar distance, and thereon insert the parts of the Milky Way, as furnished by the sections, in order to deduce a true picture of the gradation of light in the different sections. Three different ways were employed to determine the uniform scale of light. First, different spots and parts of the Galaxy were numbered, and written down directly from the sky in order of brightness; then notice was taken of the order in which the different portions of it appeared from first twilight to complete darkness and, lastly, the order in which they disappeared with the rising Moon. To be free from bias, in carrying the work forward, the author avoided all pictures of the Milky Way which had been previously made until the drawings were completed. The last stage of the work consisted in the three enlarged sections covering the whole of the Milky Way, and the general chart as they appear in the finished work.

The best way to see the fainter details of these plates is to view them at a distance of five or ten feet, for the evident reason that the contrast between faint nebulosity and the surrounding white ground is lessened the larger the area of the retina of the eye, that is covered by the image of the nebulosity. Celestial photographers are taking advantage of this physiological fact in the use of wide angled lenses to vary the area of the field of view to get contrast, for the study of details in the grouping of the stars.

XUM

The comparison of these drawings with the excellent ones by Heis, at once shows that the details of the former are more full and varied. Bœddicker does not attempt to give the faint luminosity surrounding the Milky Way proper as Heis does, because he does not feel sure that it is confined to it. To his eye the sky is covered by irregular patches of faint luminosity, and hence is not everywhere uniformly black. The attempts to represent the lunes and rifts with true light scale has proved a very hard task as every artist knows, but it is agreeably surprising to notice how well it is done in this new work. Astronomers interested in this kind of study will find these drawings a great help in studying the Galaxy which, without much doubt, is the key to the structure of the universe.

The size of these plates is 18 inches by 23 inches, and the price in folio is $10.00.

Aurora at Mt. Hamilton.—Up to the present observations, I had never seen the aurora at Mt. Hamilton.

On May 18*d* 8^h 35^m standard Pacific time (8 hours slow of Greenwich), while comet seeking on the roof of the Observatory, my attention was attracted to the northeast by two rather slender yellowish beams of light shooting vertically from the horizon near the star Alpha Cephei. I at once recognized in these the characteristic auroral streamers. The two beams were each about one degree in diameter and extended to an altitude of some 20°, the distance between them being about 3° or 4°. They were conspicuous then for a few minutes but finally merged into a single broad beam which faded quite rapidly. By 8^h 45^m no trace of the display remained, nor did it return again up to as late as moonrise. E. E. BARNARD.

Mt. Hamilton, May 19th, 1892.

Aurora at Providence, Rhode Island.—A most beautiful and brilliant display of aurora borealis occurred here last night. It was first seen at our Observatory soon after eight o'clock. At that time it was not very brilliant, but consisted of long streamers which shot up from the north and northwestern horizon, to a point near the dipper in the Great Bear. At nine o'clock it faded away. About ten o'clock it quickly brightened up again, and consisted of two distinct arches extending from the northwest near Venus, Castor and Pollux to a point in the northeast near the Cross in Cygnus. On the horizon the so-called dark segment was easily seen, and the stars of Cassiopiea shone as through a thick fog. The most brilliant part of the Aurora was between Cassiopiea and Polaris. This was of a most dazzling yellow light. About eleven o'clock the aurora was at its height and consisted of the two arches which were broken up into streamers, some of the streamers extending as far south and west as α Virginis. The light was very bright and resembled a moonlight night. At times the streamers seemed almost to unite at a point near Arcturus to form a crown, but no well defined crown was formed. From half-past eleven until after two o'clock the aurora gradually faded, and by two o'clock nothing was left of it but a few patches of white light near the northern horizon. The display of last night was one of the finest of the year, none equaling it except the one of Feb. 13. The color of this Aurora was white and yellow, the red color which usually accompanies brilliant displays being absent. At the time of greatest brilliancy, and when it broke up into streamers, the horizontal magnetic needle was greatly disturbed as usual. No observations were taken here with the spectroscope. The observations with the magnetic needle were made by Professor C. Bates Johnson.

Providence, May 19, 1892. F. E. SEAGRAVE.

XUM

Occultation of Uranus, April 12, 1892.—At Toronto this occultation, which took place at $11^h\ 51^m\ 4^s$ Eastern standard time, was well seen. Sky clear, air steady, definition good. Uranus was picked up at $11^h\ 15^m$ and easily followed up to bright limb of the Moon. Approach seemed rapid; and disappearance almost instantaneous, though planet was shown with appreciable disc. At distance of about Moon's breadth, Uranus seemed to be of same color as Moon when eye has become accustomed to her glare, but as the planet approached, his disc took on a greenish tinge which deepened until occultation; same tint was seen on emergence at $1^h\ 10^m$ A. M. Tint faded, until 2 o'clock, normal color was restored. Observation made with ten and one-quarter inch With-Browning reflector, power of 144, and Barlow lens. Planet picked up with Kelner eye-piece, power, 60; all powers showed disc. G. E. LUMSDEN.

At the Seagraves Observatory the planet was well seen even in contact with the Moon's bright limb near the emersion. The time of emersion is very uncertain as light clouds covered the Moon at that time.

IMMERSION.

	h	m	s
First contact	*12	5	7.5
Second contact	12	5	11.0

EMERSION.

	h	m	s
Mean of both contacts	13	32	21

F. E. SEAGRAVES.

Proceedings of Harverford College Observatory, 1891.—This volume contains an Investigation of the Parallax of the double star δ Herculis $= \Sigma\ 3127$, the Results of Double Star measures, Observations of Comet Wolf, made during 1891, and Sun-spot observations from April 1890 to Dec. 31, 1891. The first mentioned work is by the Director of the observatory, F. P. Leavenworth, and depends upon micrometrical measures of position angle and distance of the companion from the principal star on 45 nights from June 20, 1889, to Nov. 30, 1891. Mr. Leavenworth has taken great pains to determine the effect of personal equation depending upon the position of the eyes relative to the line joining the stars and the angle from the meridian. The measures of position angle were taken with the eyes in three different positions, viz.: normal, that is perpendicular to the line joining the stars, parallel to the same, and horizontal. The position angle for 1891.0 was approximately 187° and the distance 16″. The results indicate that the personal equation varies considerably both with the position of the eyes and with the hour angle and that, in this case, the measures with the eyes normal are the most accurate. The final value obtained for the parallax of δ Herculis is $\pi = +\ 0.050'' \pm 0.014''$. H. C. W.

Annual Report of the Observatory of Paris.—The report of the Director, Admiral Mouchez, as usual indicates a large amount of work being done at the Observatory. We notice that the number of meridian circle observations for the year 1891, by nine observers, foots up to 19,458. Messrs. Loewy and Puiseux have been engaged a large part of the time in the adjustment and study of the instrumental constants of the new equatorial *coude*. The Messrs. Henry began in September the regular work of charting by photography their assigned zone of the sky, and obtained during the year 133 plates. M. Deslandres has been actively at work in the new department of the Observatory devoted to spectroscopy and has achieved marked success in photographing the chromosphere and prominences of the Sun. Considerable space in the report is given to the meeting of the International Committee on the Photographic Chart of the sky, which was held at Paris in March and April of last year. H. C. W.

* Very uncertain by several seconds.

The Opposition of Mars in 1892.—A circular prepared by Professor Eastman of the U. S. Naval Observatory contains the following information: The determination of the solar parallax by means of meridian observations of Mars at opposition was attempted in 1862 and again in 1877. The results obtained in those years have been generally considered by astronomers as numerically too large.

The opposition of Mars, early in August, 1892, will afford another opportunity for employing the method used in 1862 and 1877. The observations and results obtained in 1877 indicated the probability of a systematic error in the observations of Mars, or of the comparison stars, or perhaps of both. It is believed that a modification of the usual method of observing would eliminate, at least, one probable source of systematic error in observing. For this reason, and for the purpose of testing the reality of the apparent coincidence of the values of the parallax obtained in 1877, and by Mr. Stone in 1862, it is earnestly hoped that all observatories having the necessary equipment, and especially all those in the southern hemisphere, will cordially coöperate in the proposed observations of Mars and the comparison stars according to the following program:

METHOD OF OBSERVING.

1. It is essential that all the observatories in the southern hemisphere that are provided with meridian circles of more than 4.5 inches aperture, and at least an equal number of northern observatories, should participate in the observations.

2. Each meridian circle used in the observations should be provided with a small reversing prism placed in a short cap, or cell, fitted to slide over the outer end of the eye-piece. The prism should be mounted on the end of a lever pivoted at one side of the cell, with the longer end of the lever projecting from the side of the cell about half an inch. With this adjustment of the lever, the prism can be quickly placed at will in the emergent pencil of rays before it reaches the eye, and the image of the object reversed. As soon as the bisection is made a slight pressure on the lever throws the prism out of the line of sight. Half of the bisections of Mars and of each star should be made each night in the ordinary way, and half when the object is viewed through the prism. It must be borne in mind that the use of the prism is absolutely essential to the success of the work.

3. In order to eliminate all errors depending on the positions of the comparison stars, every observer should, in every instance, observe the stars selected for the given night, and in no case depart from this rule.

4. The observations should begin on June 20, and continue on every favorable night until September 23.

5. One bisection, and two, if possible, should be made on each side of the center of the field. No observations of right ascension, except one transit over the central thread, should be attempted unless a chronograph is used.

6. The method used in 1877, for obtaining the position of the center of Mars, is so well adapted to secure the desired result that it is adopted, with the modifications described in paragraph 2 of this paper, for the work of 1892. The method is as follows: Two threads of equal size are inserted in the movable declination system of the field of the telescope, the distance between them being about 3″ or 4″ less than the minimum diameter of Mars during the proposed period of observation. This distance will be about 16″ for the opposition of 1892. The observation consists in moving these threads until the two small segments of the planet, outside of the threads, are seen to be exactly equal. If the thread nearest the micrometer head be disignated as thread *a* and the other as thread *b*, then the comparison stars should be observed by bisecting the *first*, *foruth*, *fifth*, and *eighth* stars with thread *a*, and *second*, *third*, *sixth*, *seventh* and

stars with thread *b*. This order should be reversed on alternate nights; but in all cases the thread used in the observation should be carefully recorded for each star.

7. The inclination of the threads used should be carefully determined during the progress of the work.

8. The division errors of the circles should be invested, at least in the vicinity of those divisions used in the observations.

9. Whenever the circle microscope threads are moved more than half the distance between the adjacent divisions they should be read on each division.

10. In making the bisections the telescope micrometer thread should be moved in all cases towards the spring against which it acts.

11. The periodic errors of all the micrometer screws should be investigated.

12. It is desirable that an ocular of a power of 150, at least, be used on all the smaller instruments, the larger ones using a power of from 150 to 200.

THE OBSERVING LIST.

The comparison stars have been so selected that the transit of four in each group takes place *before* that of the planet and four *afterward*, and, also so that the mean declination of the group is nearly the same as the mean declination of Mars for the time each group of eight stars is used.

The positions of the stars in the following list are the approximate places for 1892.0; and the positions of Mars are given for the time of transit at Washington.

The time is divided into three periods and the positions of Mars are given for the beginning and end of each period, and also for those days when the maximum and minimum right ascensions occur in each period.

OBSERVING LIST.

OBJECT.	Mag.	α			δ	
		h	m	s	°	′
From June 20 to July 26.						
O. Arg. S. 20970	7.0	20	50	38	−22	25.1
η Capricorni	5.0	20	58	15	20	16.8
27 Capricorni	6.5	21	3	23	20	59.2
ϕ Capricorni	5.5	21	9	30	21	5.9
Mars, June 20		21	19	32	20	6.8
Mars, July 6		21	25	41	20	51.7
Mars, July 26		21	15	29	22	49.9
Lacaille, 8851	6.0	21	29	5	23	56.2
41 Capricorni	5.8	21	35	51	23	45.0
D. M. −20°, 6923	7.5	21	41	42	20	4.3
Lalande, 42700	7.2	21	49	37	21	38.8
From July 27 to August 10.						
Lacaille, 8463	6.2	20	23	11	−22	45.1
Lacaille, 8506	7.0	20	31	41	24	36.2
17 Capricorni	5.9	20	39	54	21	54.3
Lacaille, 8612	7.0	20	46	42	24	11.2
Mars, July 27		21	14	32	22	56.2
Mars, Aug. 10		20	59	41	24	9.0
Lacaille, 8813	6.0	21	19	36	24	17.2
Lacaille, 8832	7.8	21	24	12	25	40.0
Lacaille, 8851	6.0	21	29	5	23	56.2
O. Arg. S., 21562	7.8	21	35	24	22	25.3
From August 11 to September 23.						
O. Arg. S., 20429	7.0	20	15	6	−23	49.1
Lacaille, 8463	6.2	20	23	11	22	45.1
Lacaille, 8506	7.0	20	31	41	24	36.2
17 Capricorni	5.9	20	39	54	21	54.3
Mars, August 11		20	58	38	24	12.5
Mars, September 4		20	44	19	24	3.0
Mars, September 25		20	53	57	22	6.7
Lacaille, 8734	7.0	21	7	1	25	17.2
Lalande, 41404	7.5	21	14	32	22	50.7
ζ Capricorni	4.0	21	20	30	22	52.8
37 Capricorni	6.2	21	28	47	−20	34.0

U. S. NAVAL OBSERVATORY, April 29, 1892.

BOOK NOTICES.

An Elementary Treatise on the Differential Calculus with Applications and Numerous Examples. By Joseph Edwards, M. A., Formerly Fellow of Sidney Sussex College, Cambridge, England. Second Edition, Revised and Enlarged. Publishers, Messrs. McMillan & Co., London and New York, 1892, pp. 521. Price $3.50.

Not having examined the previous edition of this book we are only able, in a general way, to indicate the changes made in the revision before us. The author claims that it is considerably enlarged, that the chapters have been added on maxima and mimima of several independent variables, on elimination; on Lagrange's and Laplace's theorems; on changing the independent varible, one chapter giving a short account of the principal properties of the best known curves which may be convenient for reference. And many sets of easy examples especially illustrative of theorems and methods proved or explained in the immediately preceding book-work.

The author uses mainly the method of limits and has prepared the revision with care, extending the scope of the book as originally written to meet the requirements of the best teachers who claim that the standard of work in the Calculus should be materially raised.

The first two chapters are devoted to definitions and fundamental propositions, the third gives the standard forms, and then follow the topics of successive differentiation, expansian, partial differentiation, tangents and normals, asymptotes, singular points, curvatures, envelopes, curve tracing, some well-known curves.

The final chapters on application treat of undetermined forms, maxima and minima with one or two variables, elimination, expansions continued, and the change of the independent variable.

The matter and the plan of the text seem to be very good, and the publishers have done their part neatly and well.

Logarithmic and other Mathematical Tables by William J. Hussey, Assistant Professor of Astronomy in the University of Michigan. Second Edition. Ann Arbor, Michigan. The Register Publishing Co., 1892, pp. 148.

This is a book of five place tables and it is very conveniently arranged. The first is a table of common logarithms from 1 to 1000 with auxiliaries for sine and tangent in seconds of arc, the second is for addition and subtraction of natural numbers, and the third and fourth are for trigonometric functions, the fifth gives the natural trigonometric functions, sixth squares, cubes, square roots and cube roots from 1 to 1020. The figures of the tables are old style, with an easy, clear face, and the page is conveniently divided by heavy and light rule, so that the computer can instantly find what he wants. If the tables are accurate (we have no reason to believe they are not), this book will prove to be a popular one. The three pages of astronomical and mathematical constants at its end contain very useful matter.

An Elementary Course in Theory of Equations By C. H. Chapman, Ph. D., Associate in Mathematics in Johns Hopkins University. Messrs. John Wiley & Sons, Publishers, 53 East Tenth St., New York, 1892. 12 mo. cloth pp. 90. Price $1.50.

This small book interests us at sight. In ninety pages the author has brought together the principles of Determinants and the Theory of Equations in such a way as to suppose only, on the part of the student, a good knowledge of algebra and some acquaintance with trigonometry and calculus, and is therefore suitable for a college text-book or for private study. We are sure he is right in saying that a knowledge of Determinants and the Theory of Equations is necessary to those beginning the study of the modern higher mathematics, and it is also true that most texts on these subjects are too extended and exhaustive for the College student. It has been the aim of this author to introduce only such parts of the themes as are most profitable for actual practice in the mathematical investigation. The first twenty pages treat of Determinants in elemental way, furnishing a variety of examples to illustrate the principles and the operations. The second part of the book treats of algebraic equations and embraces forty pages, and the third part is devoted to the computation of the real roots of numerical equations.

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It will be an advantage to the student to be somewhat acquainted with the elementary processes of Determinants to read the first part of this little book easily. If not so acquainted, he may find it so condensed in statement and limited in illustration, that progress will be slow.

A Hand-Book of Practical Astromony for University Students and Engineers. By W. W. Campbell, formerly Instructor of Astronomy in the University of Michigan; Astronomer in the Lick Observatory. The Register Publishing Company, Ann Arbor, Michigan, 1891. pp. 166.

The fact that the larger treatises on practical astronomy can not be used satisfactorily with undergraduate students is the reason that the author has prepared another new book better adapted to the wants of the considerable number of students in colleges and universities who are now turning their attention to Astronomy more generally than heretofore. This book is the outgrowth of a system of instruction in the form of lecture notes to large classes in practical Astronomy in use at the university of Michigan.

The order of topics is the same as that found usually in handbooks of this kind. The twelve chapters treat respectively of the following subjects:—The celestial sphere, time, transformation of cöordinates, correction of observations, precession, nutation, etc., angle and time measurement, the sextant, the transit instrument, the zenith telescope, astronomical azimuth, the surveyor's transit, the equatorial and an appendix giving hints on computing, combination and comparison of observations, list of objects for the telescope, refraction tables and reductions to the meridian and elongation.

In presenting these topics the formulæ are given with references usually to Chauvenet's trigonometry. They are briefly explained, illustrated by examples in which the form of work and solution are made prominent. Many of the figures, in illustration of the topics are new and seem to us well chosen. If the engraver had done his work better, in some instances, it would have materially added to the good appearance of the page. This text seems to be well considered in detail, and we think it well adapted to the place for which it is prepared.

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